UNIV. OF
TORONTO
LIBRARY

Digitized by the Internet Archive
in 2011 with funding from
University of Toronto

http://www.archive.org/details/journalglasstech03soci

JOURNAL OF THE
SOCIETY OF GLASS TECHNOLOGY

P
Tech
A
B

JOURNAL

OF THE

SOCIETY OF GLASS TECHNOLOGY

111

COMPRISING

PROCEEDINGS AND REPORTS, TRANSACTIONS

AND

ABSTRACTS OF PAPERS FROM OTHER JOURNALS

Editor

W. E. S. Turner, O.B.E., D.Sc., M.Sc.

Abstractors

H. G. Cameron
J. D. Cauwood, M.Sc., A.I.C.
J. R. Clarke, M.Sc.
J. H. Davidson, M.Sc., F.I.C.
Violet Dimbleby, B.Sc.
G Dowse, B.Sc.
S. English, M.Sc., A.I.C.
Adeline M. Jackson, B.Sc.
Constance M. Muirhead, B.Sc.
F. W. Hodkin, B.Sc., A.I.C.

452564
12. 10. 46

1919. Vol. III.

Published by the Society of Glass Technology.
Secretary Dr. W. E. S. Turner, The University, Sheffield.

PRINTED IN GREAT BRITAIN BY
Richard Clay and Sons, Limited,
BRUNSWICK STREET, STAMFORD STREET, S.E. 1,
AND BUNGAY, SUFFOLK.

TP
845
S73
v.3

The Society of Glass Technology.

The Society of Glass Technology was inaugurated at a meeting in the University of Sheffield, on Thursday, November 9th, 1916.

Its object was defined as the general advancement of the various branches of Glass Technology by the association of persons interested in glass and glassware; the reading and discussion of papers; the publication of scientific information on glass technology; the formation of a library and museum.

All persons or associations of persons interested in glass, whether from the point of view of the manufacturer, the distributor, the scientist, the user or collector, are eligible for membership.

Membership is of three classes: Collective Membership, open to Firms, Associations, and Committees; Ordinary Members, and Student Members, the annual subscription in each class being £3 3*s*., £1 10*s*., and 2*s*. 6*d*. respectively. Copies of the Constitution and Rules may be had on application to the Secretary, The University, Sheffield. The total number of members whose election has been confirmed exceeds 500.

Meetings of the Society are arranged monthly, except during the summer. One half of the meetings take place at Sheffield, the headquarters of the Society, the other meetings being held in different centres of the glass industry, as the Council decides. In this way local interest is stimulated.

The Society publishes a Quarterly Journal, containing the papers read to the Society and the discussions on the papers, together with abstracts of other papers of interest to members published in British and foreign journals. Each collective member may receive two copies and each ordinary member one copy.

Scientific communications on glass technology are invited for publication in the Journal.

A library of technical literature has been formed, and a list of the books available for reference or for loan may be obtained from the Secretary.

The Society of Glass Technology.

LIST OF OFFICERS FOR 1919-20.

President:

S. N. JENKINSON.

Past-President:

W. F. J. WOOD, C.B.E., B.Sc., F.I.C.

Vice-Presidents:

G. E. ALEXANDER.
S. B. BAGLEY.
Prof. P. G. H. BOSWELL, O.B.E., D.Sc., D.I.C.
F. W. BRANSON, F.I.C.
Prof. J. W. COBB, C.B.E., B.Sc., F.I.C.
J. E. FOXON.
CONGREVE JACKSON.
S. W. MORRISON, O.B.E.
HARRY J. POWELL, B.A.
Col. C. W. THOMAS.
M. W. TRAVERS, D.Sc., F.R.S., F.I.C.
H. S. WILLIAMS-THOMAS.

Council:

MILTON ASQUITH.
W. R. BARKER.
R. S. BIRAM.
F. J. BOAM.
WM. BUTLER.
F. G. CLARK.
J. CONNOLLY.
THOMAS DAVIDSON.
S. ENGLISH, M.Sc.
Prof. W. G. FEARNSIDES, M.A.
W. J. REES, F.I.C.
J. S. SHAW.
F. SWANN.
W. W. WARREN.
DUNCAN WEBB, Jun.

Treasurer:

F. SWEETING.

Secretary and Editor:

W. E. S. TURNER, O.B.E., D.Sc., M.Sc.

Assistant Secretary:

C. J. PEDDLE, M.Sc., F.I.C.

Auditors:

G. WILSON CLARKE.
FREDERICK LAX.

VI

PROCEEDINGS

/

PROCEEDINGS
OF THE
SOCIETY OF GLASS TECHNOLOGY

PROCEEDINGS OF THE TWENTY-FIRST MEETING.

HELD in the Physics Lecture Theatre, The University, Western Bank, Sheffield, at 2.30 p.m. Wednesday, December 18th, the President, Mr. W. F. J. WOOD, in the Chair.

Mr. S. W. Morrison, O.B.E., was elected as a Vice-President of the Society to fill the vacancy created by the death of Mr. A. S. Esslemont.

Mr. R. S. Biram was elected an Ordinary Member of Council to fill the vacancy due to the resignation of Mr. A. R. Young.

The following papers were read:—

"A Rapid and Accurate Method of Calibrating Burettes," by S. English, M.Sc., A.I.C.

"Bottle Glass and Glass Bottle Manufacture," by W. E. S. Turner, D.Sc.

The President and Mr. V. Stott joined in the discussion of the former paper, which was illustrated by a demonstration of the apparatus.

The following were elected as members of the Society:—

Ordinary Members.

H. M. Read, The Briers, North Park Avenue, Roundhay, Leeds.
A. Brann, B.A., M.A., Ph.D., Messrs. The Westinghouse Lamp Co., Bloomfield, New York.
W. Proctor, Thornaby Glass Works, Thornaby-on-Tees.
W. L. Foster, Major, D.S.O., Messrs. Chance Bros. & Co., Ltd., Glass Works, Smethwick, Birmingham.
James Field, General Manager, Messrs. Chance Bros. & Co., Ltd., Glass Works, Smethwick, Birmingham.

PROCEEDINGS OF THE TWENTY-SECOND MEETING.

HELD in the School of Technology, Manchester, on Wednesday, January 15th, at 3.15 p.m., Mr. DUNCAN WEBB, Vice-President, in the Chair.

The following paper was read:—

"Manufacturing Costs in the Glass Industry," by J. D. Mills, Chief Accountant of the Optical Munitions Branch of the Ministry of Munitions.

An excellent discussion followed, in which Messrs. F. Sweeting, J. Connolly, S. N. Jenkinson, F. Edward, Julian Osler, and the Chairman joined.

During the morning visits had, at the kind invitation of the Directors in each case, been paid by the members to the following works:—

Messrs. Ford Motor Co., Trafford Park.

Messrs. Burtles, Tate & Co., Ltd., Glass Works, Poland Street, Manchester.

Messrs. Molineaux, Webb & Co., Ltd., Manchester Flint Glass Works, Kirby Street, Manchester.

Messrs. William Nelson & Co., Ltd., Ancoats Glass Works, Pollard Street, Manchester.

A very hearty vote of thanks was passed to the Directors for their kindness and hospitality.

A vote of thanks was passed to the Governors of the Municipal Technical College, and to the Principal, Mr. J. C. Garnett, for their kindness in providing accommodation for the Society's meeting.

Mr. J. Connolly was cordially thanked for his services in making arrangements for the meeting.

The following members were elected:—

Collective Members.

Messrs. British & Foreign Bottle Co., 107, Cannon Street, London, E.C.4.

Ordinary Members.

G. A. Squires, Glasshouse Pot Maker, 2, Brunton Terrace, Sunderland.
W. D. Hartshorn, 11, Wensom Street, Norwich.
H. Vickers, Messrs. Wood Bros. Glass Co., Ltd., Barnsley.
Major C. W. Thomas, Clifton House, Oldswinford, Stourbridge.
R. H. Dowell, Messrs. J. H. Dowell & Sons, Ltd., Globe Works, Chatsworth Road, Clapton Park, London, N.E.
C. A. Chidell, Messrs. South African Breweries, Ltd., 8, 9, and 10 Gt. St. Helens, London, E.C.3.
G. D. Macbeth, Ph.D., Messrs. Macbeth Evans Glass Co., Pittsburgh, U.S.A.

PROCEEDINGS OF THE TWENTY-THIRD MEETING.

HELD in the Physics Lecture Theatre, The University, Western Bank, Sheffield, at 3.0 p.m. on Wednesday, February 19th, Mr. J. CONNOLLY occupying the Chair in the absence of the President.

The following papers were communicated, the first and third being read by Dr. Turner, the second being taken as read:—

"The Properties of the Lime-Soda Glasses. II. The Resistance to Water and other Reagents," by J. D. Cauwood, M.Sc., Constance M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

"Note on a German Fireclay Tank Block," by W. E. S. Turner, D.Sc.

"The Properties of the Lime-Soda Glasses. III. The Thermal Expansions," by S. English, M.Sc., and W. E. S. Turner, D.Sc.

Prof. P. G. H. Boswell gave an account of his visit of inspection of the sand, clay, and glass industries of the United States at the end of 1918.

During the morning a visit was paid, at the kind invitation of the Directors, to the works of Messrs. Beatson Clark and Co., Ltd., Rotherham. A hearty vote of thanks was passed to the firm for the privilege extended.

The following members were elected:—

Collective Members.

Messrs. John Walsh Walsh, Ltd., Soho and Vesta Works, Birmingham.
Messrs. Taylor, Taylor, and Hobson, Ltd., Optical and Scientific Instrument Makers, Stoughton Street Works, Leicester.
Messrs. Naylor Bros., Denby Dale, nr. Huddersfield.
Messrs. United Kingdom Glass Co., Ltd., 107, Wool Exchange, Coleman Street, London, E.C.2.
Messrs. South African Glass Works, Ltd., Johannesburg.
Messrs. Lambeth Glass Works, Ltd., Dashwood House, New Broad Street, London, E.C.2.

Ordinary Members.

S. Barraclough, Union Foundry, Barnsley.
H. Thomas, Messrs. J. Wright & Co., Ltd., Essex Works, Birmingham.
W. A. Norton, Messrs. Wm. Brooke (Leeds), Ltd., Hunslet, Leeds.
P. B. Stephens, Messrs. Wm. Brooke (Leeds), Ltd., Hunslet, Leeds.
H. Wright, 19, Foxberry Road, Brockley, London, S.E.
R. McInnes, Messrs. Scientific Supplies Co., Ltd., 52, Hatton Garden, London, E.C.
A. F. Gorton, B.A., M.A., Ph.D., The Buckeye Clay Pot Co., Toledo, Ohio, U.S.A.
Jan Berghuis-Krak, B.Sc., West Virginia Geological Survey, Morgantown, N.Y., U.S.A.
Col. T. W. Simpson, Messrs. J. Lumb & Co., Ltd., Castleford.
B. J. Allen, The Vacuum Casting Co., 1, Buckingham Street, Strand, London, W.C.2.
Wm. Newbould, Furnace Builder, 71, Church Street, Hunslet, Leeds.
H. Pemberton, Glasshouse Pot Maker, Nook Street, Hillidge Road, Hunslet, Leeds.
Lieut.-Col. Oscar Lewis Eugster, I.S.C., British Syphon Mfg. Co., Barnsbury Street, London, N.

Student Member.

Donald Turner, 41, Coverdale Road, Sheffield.

BYE-LAWS FOR BRANCHES OF THE SOCIETY ABROAD.

The foreign membership of the Society is steadily increasing, and the Council, in its desire to place its advantages at the disposal of all members, has adopted the following Bye-laws in order to encourage the closer association of groups of members abroad.

Proposed Bye-laws for Governance of Sections Abroad.

(1) The Council may at its discretion, upon receipt of a request from a sufficient number of Members, Collective and Ordinary, resident abroad in any country, create a Section or Branch of the Society for that country, and it shall also have power to dissolve such a section at any time after it has been formed.

(2) Such Sections as are referred to in (1) shall be managed by a Sectional or Branch Council or Committee elected by the Members of the Section.

(3) The Council or Committee of the Section shall prepare rules for the government of the Section, and these rules shall be submitted to the Council of the Society for approval.

(4) A certain sum, to be fixed from time to time, based on the cost of printing and distribution of notices of meetings, stationery, and incidental expenses, shall be put at the disposal of the Section or Branch. Beyond this amount, the Section shall not be a charge on the Society nor shall the Society be responsible for liabilities incurred by the Section.

(5) Complete reports of each Meeting held by a Section or Branch shall be forwarded to the Secretary of the Society, and these reports shall form the basis of a report in the Proceedings of the Society.

(6) Each Section or Branch shall appoint a small Publications Committee to examine all papers contributed and reports of discussions held at the Sectional Meetings, and the Publications Committee shall then forward to the Secretary of the Society all such papers as are deemed worthy of publication.

REPORT TO THE COUNCIL FROM THE REFRACTORIES RESEARCH AND SPECIFICATIONS COMMITTEE.

The Committee has pleasure in presenting the following report on its labours during the past eight months:—

General Policy.

Since its appointment by the Council, as the result of representations made by a Conference held at the Ministry of Munitions in July, 1918, the Committee has held five meetings, whilst the various Sub-Committees have also held several meetings and have engaged in voluminous correspondence.

At the first of the meetings of the Committee, held on August 12th, 1918, at King's College, London, the general policy of the Committee was discussed and settled. It was decided that it was essential to produce at as early a date as possible a set of Provisional Specifications dealing with:—

(*a*) Tank blocks,
(*b*) Clay for glass pots and grog,
(*c*) Silica bricks and blocks,
(*d*) Miscellaneous refractories,

based on a combination of such scientific data as existed and the best practical experience. Such Provisional Specifications were needed urgently for the guidance of glass manufacturers, furnace builders, and the suppliers of refractory materials. At the same time, it was decided that researches into the nature and properties of refractory materials suitable for glass making were called for on an elaborate scale, and that steps should be taken to have these set on foot and the results embodied in a fuller series of Specifications at a later date.

The Work of the Committee.

The work of the Committee fell, therefore, into three sections:—

(1) The collection of data towards a Provisional Specification.

(2) The planning of a research programme which should yield speedy results, yet be capable of indefinite expansion.

(3) The provision of funds both to meet the expenses incurred during the setting up of the Provisional Specification and to finance the researches required.

In order to obtain data on the best experience extant, circulars were issued to glass manufacturers inviting them to give information along certain lines based on experience with the refractory materials in use. A number of replies was received giving very useful information in several cases, although the response, on the whole, was not quite so good as hoped for. These data were passed on for consideration to four Sub-Committees, each dealing with a distinct body of problems, as it was thought that only by subdivision of the work could Specifications be drafted expeditiously. The four Sub-Committees and their constitution are as follows:—

Committee on Fireclay Bricks and Blocks.—Prof. J. W. Cobb, Messrs. J. Connolly and W. J. Rees (Chairman), and Dr. J. Mellor (co-opted).

Committee on Glass Pots and Raw Clay and Grog for Glass Pots.—Messrs. J. H. Davidson, S. N. Jenkinson (Chairman), C. J. Peddle, Duncan Webb, and Dr. M. W. Travers.

Committee on Silica Refractories.—Prof. J. W. Cobb, Mr. W. J. Rees (Chairman), and Dr. J. W. Mellor.

Committee on Miscellaneous Refractories.—Prof. J. W. Cobb (Chairman), Messrs. S. N. Jenkinson and W. J. Rees.

The President and Secretary were *ex-officio* members of these Committees.

These Sub-Committees did not include any manufacturers of refractory materials. It was considered advisable in the early stages of the discussion that glass manufacturers and their scientific advisers should draw up a statement of the requirements of the industry, and that at a later date refractories manufacturers should be invited to join the Committee, when the proposed specification could be discussed in the light of practical manufacturing considerations.

Information for the guidance of the Committee was also sought from two additional sources. The first, namely, the Committee on Standards of the American Ceramic Society, is likely to help by its criticisms and advice in the future. Although as yet no comments have been received on Provisional Specifications forwarded for criticism, the Chairman of the Standards Committee has expressed his pleasure at the opportunity for co-operation. The second source was the discussion on refractory materials, held at the October meeting of the Society, arranged purposely with the object of eliciting opinions. Five papers were contributed and discussed, namely, "Refractory Materials and the Glass Industry," by Prof. J. W. Cobb; "Note on the Firing of Glass Pots," by Dr. M. W. Travers; "The Requirements of Clay for the Glass Industry," by S. N. Jenkinson; "Note on the Solubility of Pot Material in Glass," by J. H. Davidson and Dr. W. E. S. Turner; "Notes on Pot Attack," by C. Coad-Pryor.

The task of drawing up a research programme was committed to a Research Committee, consisting of the President and Secretary with Messrs. Jenkinson, Rees, and Morrison, and Dr. Travers, and it was determined that the problems recommended for immediate investigation should be those likely to yield results leading to a marked improvement in glass refractories at an early date. It was decided that the Delegacy for Glass Research, Sheffield, should be approached to carry out the proposed tests on clays, and Prof. Cobb and Mr. Rees those on fireclay bricks and blocks, in the research programme.

Financial Assistance from the Ministry of Munitions.

In regard to the provision of funds for the prosecution of research, the Ministry of Munitions, Glassware Munitions, recognised the need for immediate assistance, and was successful in obtaining from the Treasury for the purpose a grant of £1,000, with a further grant of the same amount if a satisfactory report was presented by the Committee within six months after receipt of the grant.

The Committee was also of the opinion that an application to the Advisory Council for a large grant ought to be made, and the Secretary was instructed to prepare a case and to make arrangements for a deputation to lay the case before the Advisory Council.

Application to the Advisory Research Council.

The consideration of the case occupied most of the second meeting of the Committee, held at the Institute of Chemistry, Russell Square, on September 25th, and a deputation, consisting of Sir Herbert Jackson, Dr. Travers, Sir Harry Seymour Foster (representing the Glaziers' Company), Messrs. S. N. Jenkinson, J. H. Davidson, J. Connolly, W. J. Rees, and Dr. Turner met the Chairman and Secretary of the Advisory Research Council, and Mr. Davies, representing the Board of Education, and discussed the matter very thoroughly. As a result, it was resolved to draw up a fresh case, setting forth the position of the industry and its claim for special treatment, and this was done. Although renewed applications have been made on behalf of the Society, the Advisory Council ultimately decided to let the application remain in abeyance, and to press the glass industry to form a Research Association, the objects of which should include the investigation of furnace constructional materials.

The Finance Committee.

For the present, therefore, the researches on refractories have necessarily to be conducted on a modest scale. The oversight of the finances was entrusted to a Finance Committee, consisting of the President, Messrs. S. N. Jenkinson, S. W. Morrison (Chairman), W. M. Gibbons (Treasurer), and Dr. Turner.

Co-operation with the Refractories Manufacturers.

At the third meeting of the Committee, held on October 15th, 1918, draft specifications were presented by three of the Sub-Committees, namely, those on Tank Blocks, Raw Clay and Grog for Pots and Silica Refractories, and after discussion were sent forward to the Council. After consideration of the reports, the Council, on October 23rd, thought the time ripe to invite the opinions and co-operation of the manufacturers of refractory materials, and an invitation, therefore, was addressed to the Employers' National Council for the Clay Industries inviting that body to nominate representatives. Eventually notice was received, on December 16th, that the following gentlemen had been nominated:—Major H. C. King, Mr. H. J. C. Johnston, Major Thomas, Mr. F. H. Brooke, Mr. W. Gardiner, Mr. Alfred Stephens, and a further meeting of the Committee was accordingly held on January 15th in Manchester, at which the representatives of the refractories manufacturers were present. Considerable advance was made, but it was decided ultimately that the manufacturers of refractory materials should first of all meet to consider the proposed specifications in detail and formulate their views, after which the full Sub-Committees, including refractories manufacturers, could hold a joint session. The refractories manufacturers were co-opted on the Sub-Committees as follows:—On the Fireclay Brick and Block Committee, Messrs. H. C. Johnston, M. Barrett, Majors H. King and C. W. Thomas; Raw Clay and Grog for Pots, Majors H. King and C. W. Thomas, and M. Barrett; Silica Refractories Committee, Messrs. W. Gardiner, F. H. Brooke, and A. Stephens.

THE COMMITTEE'S RECOMMENDATIONS.

The meetings of the refractories manufacturers and of the Sub-Committees having been held, the Committee held its fifth meeting on March 26th at the Queen's Hotel, Birmingham, and after a four hours' sitting drew up its recommendations, which are now presented. The subject of Miscellaneous Refractories had been found more difficult to deal with than the others, and it was recommended that publication of the three other Provisional Specifications appended should not be delayed for the sake of that on Miscellaneous Refractories.

The Committee feels that there is yet much work, even of a preparatory character, to be carried out. Thus, the Sub-Committee on Fireclay Bricks and Blocks has dealt as yet only with Tank Blocks, the subject of Siege Blocks still having to be discussed, whilst the Sub-Committee on Raw Clay and Grog for Pots desires presently to make recommendations on a variety of subjects, including the method of heating up glass pots and their subsequent treatment, whilst the question of standardisation of sizes and shapes is one which needs to be considered at once. Indeed, the work of the Committee appears to be but beginning, since each problem considered, like the fabulous decapitated hydra, gives rise to at least seven others.

S. W. MORRISON, *Director of Research.*
W. E. S. TURNER, *Secretary.*

OBITUARY.

We regret to announce the death of

Edwin Hopkinson, M.Sc., chemist at Messrs. Pilkington Bros., Ltd., St. Helens, and a young man of great promise.

Mr. Hopkinson had a very successful career as a student, entering the Victoria University, Manchester, as a Scholar, and graduating B.Sc. in 1902 with first class honours in chemistry. In 1903 he was awarded a University Fellowship, and later in 1903 one of the Gartside Scholarships for commerce and industry, as the holder of which he spent six months of travel and study in the United States, and a further six months in Germany. In 1904 he graduated M.Sc., and on the completion of his travels under the Gartside scheme accepted an analytical post in Manchester, where he did a good deal of work in connection with the "arsenic in beer" scare. He entered the service of Messrs. Pilkington Bros. in 1906, and by his ability and his industry soon rose to a position of much responsibility on the technical staff of this large and important undertaking. To his personal qualities very high tribute was paid by his colleagues and friends, and his death is a great loss to the industry to which he was attached.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING.

HELD in the Latin Lecture Theatre, The University (Mason College), Edmund Street, Birmingham, at 3.0 p.m., on Wednesday, March 19th, 1919, the President, Mr. W. F. J. WOOD, in the Chair.

The following paper was read and discussed:—

"The Preparation of Raw Materials for, and the Casting of, Glass Pots," by Mr. B. J. Allen.

A long and interesting discussion took place, in which Messrs. W. Butler, J. Wilkinson, M. H. Edwards, Congreve Jackson, J. S. Williams-Thomas, J. H. Davidson, and A. B. Searle took part.

During the course of the morning visits were paid, at the kind invitation of the Directors in each case, to the works of Messrs. P. Branscomb Glass Bottle Works, and Messrs. Icknield Glass Works (Oslers), Ltd. A hearty vote of thanks was passed to each of these firms for the privilege accorded.

The following members were elected:—

Collective Members.

John Hall and Co. (Stourbridge), Messrs., Ltd.	Fire Clay Works, Stourbridge.
The Indian Munitions Board (Intelligence Branch).	Delhi.

Ordinary Members.

Holdcroft, A. D.	Wavertree, Bradwell Lane, Porthill, Stoke-on-Trent.
McDowell, J. P., B.S.	Messrs. Harbison-Walker Refractories Co., Pittsburgh, Pa.
Rollin, C., D.Sc., F.G.S.	1, St. Nicholas Buildings, Newcastle-on-Tyne.
Bennett, Wm.	International Bottle Co., Ltd., 48, Fore Street, London, E.C.2.
Trewartha-James, W. H., M.I.M.E., M.C.M.I.	Manor Lodge, 4, Grove End Road, London, N.W.8.
Jackling, E.	Messrs. Thermos, Ltd., 2/4, Finsbury St., London, E.C.2.
Lum, Yukman, B.S.	Kwang Tung Glass Mfg. Co., Sen Kong, Honam, Canton.
Bullimore, W. R.	Aberdeen Works, Aberdeen Lane, Highbury Grove, London, N.5.
Haller, Percy, M.Sc.	Messrs. Forster and Sons, Ltd., Atlas Glass Works, St. Helens.
Nutting, P. G.	Westinghouse Research Laboratory, Westinghouse Electric and Mfg. Co., East Pittsburgh, U.S.A.
McKaig, W. W.	Wellington Glass Co., Cumberland, Md., U.S.A.
Murray, G.	Messrs. Gregg and Co., Knottingley.
Coppe, Jules.	16, East Street, Gateshead.
Sosman, R. B., Ph.D.	Geophysical Laboratory, Washington, D.C.

PROCEEDINGS OF THE SECOND ANNUAL GENERAL MEETING.

Held in the Metallurgical Lecture Theatre of the University, St. George's Square, Sheffield, at 2.15 p.m., April 16th, 1919, the President, Mr. W. F. J. Wood, in the Chair.

The Annual Report of the Council, together with the Balance Sheet, for the year 1918 had been circulated, and after being open for comment were approved.

The Report and Balance Sheet are as follows:—

The Society still continues to grow, with no sign of diminution in the number of applications. On January 1st, 1918, the net membership stood at 264. During the year the election of 146 additional members, 44 Collective, 101 Ordinary, and 1 Student Member, took place, making the total number of elections to membership since the formation of the Society 413. As the Society lost 5 Ordinary members by death during 1918, and 5 members resigned, the net number on December 31st stood at 391. The names of the members whom the Society has lost by death are:—

Alfred Sherwood Esslemont, C.B.E.
William A. Brown.
William Robinson.
Thomas Tyrer.
Marquis de Mos.

The names of the members who have resigned are:—

Collective Member.—Messrs. Periscopes and Hyposcopes, Ltd., 39 Victoria Street, S.W.1.

Ordinary Members.—F. G. Mansfield, Messrs. Mansfield Bros., Church Gresley, Nr. Burton-on-Trent.
J. Kenworthy, Stretton Villa, Deepcar, Sheffield.
Guy Simpson, Messrs. John Lumb and Co., Ltd., Glass Works, Castleford.
G. A. Seaward, Fairfax House, Mortlake, London, S.W.

Amongst the applications for membership it has been a source of satisfaction to note that there have been quite a number from the officers of trades unions and glassworkers, thus testifying to the appeal which the Society makes to all thoughtful members of the glass industry. Another noteworthy feature, and one that is a source of great pleasure to the Council, is the large number of applications for membership from our friends in the United States.

During the year, 25 papers were communicated to the Society, as against 19 in 1917, and most of them have already appeared in print. Volume II. of the Journal contains, in addition to indexes, 30 pages of Proceedings and Reports, 26 papers comprising 294 pages of Transactions, and 296 Abstracts, in addition to Reviews occupying a total of 186 pages. The Council's thanks are again tendered to the Abstractors for their services, and particularly to Miss A. M. Jackson, B.Sc., for assistance in preparing the Annual Indexes. The number of copies printed during the past year has been 750, but the demand is becoming so considerable that it has become necessary to decide whether or not the issue cannot be considerably increased. An increased circulation will also make the Journal of greater value as an advertising medium. It is a source of satisfaction to note that the number of pages taken up by advertisers is approximately twice that of 1917.

The attendances at the meetings during 1918 have been very good, on two occasions, namely, at Stourbridge and at London, more than 100 members being present. The discussion on "The Glass Industry after the War" aroused much interest, and attracted the notice of various Government Departments as well as of Associations of manufacturers and employees. In regard to papers of technical interest, the Council would appeal to manufacturers who have been in the habit of keeping systematic records to contribute papers for the benefit of the industry in general. It is to the great advantage of the Society and of the industry that contributions shall be drawn from as many different sources as possible. Even historical notes on the development of the industry are welcomed, so long as the data have been fully authenticated.

Several additions to the Library have been made during the year. Amongst them may be noted the following periodicals, namely:—

"The Journal of the American Ceramic Society,"
"The New Zealand Journal of Science and Technology,"
"The National Glass Budget" (America),

by exchange;

"The Pottery and Glass Trades Record,"

by presentation, whilst further periodicals in the library of the Department of Glass Technology have been put at the disposal of the Society, namely:—

"Diamant,"
"Die Zeitschrift für Instrumentenkunde,"
"Die Deutsche-Mechaniker-Zeitung."

The total number of volumes in the Library is now 100.

During the year an important development took place in the formation of a Refractories Research and Specifications Committee. The constitution of this Committee, and of its Sub-Committees, has already been reported in the Journal. The work has been pursued actively during the year, and received considerable stimulus as the result of the discussion held by the Society at the October meeting.

In order to foster interest in the work of the Society abroad and to make its advantages as real as possible to members resident overseas, the Council has adopted a set of Bye Laws, permitting and regulating, the formation of Branches of the Society abroad.

The Council has signified its adherence to the Federal Council for the Advancement of Pure and Applied Chemistry, and the Secretary was appointed to represent the Society on the Federal Council. It is hoped that the strength of the Federal Council, which comprises a number of powerful Societies, will make its influence felt in the advancement of scientific methods applied to commerce and the business of the Government.

In May, 1918, the Council of the Society met in joint session with representatives of the Society of the Illuminating Engineers in London to discuss the position of illuminating glassware and its possible production in larger quantities in this country. A representative of the Ministry of Munitions was present, and the result of the deliberations was transmitted to the Ministry, Optical Munitions and Glassware Branch.

On the invitation of the Department of Scientific and Industrial Research, the Council nominated Mr. F. W. Branson, F.I.C., to be a member of the Committee on the Standardisation of Laboratory Glassware.

The income of the Society for 1918 amounted to £833 6*s*. 4*d*., as against £482 13*s*. 6*d*. in 1917, an adverse balance of £16 17*s*. 3*d*. being converted into a credit balance of £45 7*s*. 5*d*. During 1918 the cost of producing the Journal was approximately £700, out of the £788 1*s*. 11*d*. expended by the Society. The increasing cost of the Journal has been a matter of serious concern to the Council for a long time, and it is only due to the fact that all the service rendered to the Society has been voluntary that has enabled it to

SOCIETY OF GLASS TECHNOLOGY.

Income and Expenditure Account, December 31st, 1918.

Receipts.

	£	s.	d.
To Subscriptions:			
93 Collective Members at £3 3*s*. each	292	19	0
264 Ordinary Members at £1 1*s*. each	277	4	0
8 at 2*s*. 6*d*. each	1	0	0
,, Donation by T. Ferry, Esq.	2	2	0
,, Sale of Journals and Binding Cases	126	12	1
,, Bank Interest	7	5	6
	£707	2	7

Payments.

	£	s.	d.
Jan. 1.			
By Amount due to Treasurer as per statement for 1918	16	17	3
,, Printing and distribution of Journals, No. 5 and No. 6	269	3	4
,, Author's reprints, No. 5 and No. 6...	14	16	10
,, Binding 200 copies, Vol. I	10	4	0
,, Binding Cases (200)	5	16	0
,, Printing and Stationery	29	6	11
,, Library purchases	4	0	5
,, Petty Cash and Postages	29	13	1
,, Sundry Expenses	5	6	9
,, Bank Charges and Postages	3	13	0
,, Shorthand Notes and transcripts of meetings ...	10	4	4
Dec. 31.			
,, Cash in hand	308	0	8
	£707	2	7

BALANCE SHEET AS AT 31ST DECEMBER, 1918.

LIABILITIES.

	£	s.	d.
Printing and Distribution of Journal No. 7	162	15	2
Author's reprints			
Printing and Distribution of Journal No. 8	188	2	2
Author's reprints	8	0	0
Reprints of lists of members	3	16	9
Binding Cases, Vol. II	3	10	0
Binding 175 copies, Vol. II	12	13	0
Printing	5	15	10
Postages	4	4	1
	£388	17	0
Balance of Assets over Liabilities in addition to copies of Journal in Stock	45	7	5
	£434	4	5

ASSETS.

	£	s.	d.
Cash in hand	308	0	8
Due for commission on advertisements	126	3	9
Journals in stock :			
No. 1, 8; No. 2, 129; No. 3, 110; No. 4, 99;			
No. 5, 2; No. 6, 3; No. 7, 3; No. 8, 6;			
Total, 360.			
Vol. I Bound, 153; Vol. II Bound, 175. 328			
Vol. I Cases 130; Vol. II Cases, 84. 214			
	£434	4	5

We have examined the above accounts with Pass Book, Vouchers, etc., and in our opinion they are correct, and exhibit a true view of the Society's affairs as at December 31st, 1918.

G. WILSON CLARKE,
FREDERICK LAX.

April 3rd, 1919.

show a credit balance. Owing to the growth of the work of the Society it cannot longer depend entirely on voluntary service, and some clerical assistance must necessarily be engaged. The Council proposes to make certain recommendations which will enable the Society to continue its work unimpaired during 1919, when its budget will, it may safely be predicted, exceed £1,000.

The position is one that is bright with promise. Although the Society may claim already to have reached a worthy place amongst scientific societies, better things are still in store, given the enthusiasm of the past two years and the continued co-operation between all branches of the industry for which, on the technical side, the Society speaks.

The SECRETARY was called on by the PRESIDENT to explain the recommendation of the Council with regard to increasing the annual subscription of ordinary members. After the statement, it was resolved that Rule 16, relating to subscriptions, shall be amended so as to read:—

> "Rule 16.—Subscription.
>
> "The Annual Subscription shall be as follows:—
>
> "(*a*) Collective Members shall pay £3 3*s*. per annum.
>
> "(*b*) Ordinary Members shall pay £1 10*s*. per annum.
>
> "(*c*) Student Members shall pay 2*s*. 6*d*. per annum."

It was further resolved that the new rule shall come into operation on January 1st, 1920.

Amendments, of which due notice had been given, were made to Rules 3 (*c*) and 20. The rules as amended read:—

> "Rule 3 (*c*).—Student Members, *i.e.*, registered students, under the age of 21, who are attending a course or courses of technical instruction in the United Kingdom."
>
> "Rule 20.—Council.
>
> "The Council shall consist of the President, Past-Presidents, twelve Vice-Presidents, the Treasurer, Secretary and Assistant Secretary, and fifteen members, who shall be elected at the Annual General Meeting."

Messrs. J. D. Cauwood and J. R. Clarke were elected scrutineers for the purposes of the election of officers.

As the result of the ballot, the following were appointed officers for the year 1919—20:—

President: S. N. Jenkinson, M.B.E.

Past-President: W. F. J. Wood, C.B.E., B.Sc., F.I.C.

Vice-Presidents: G. E. Alexander, S. B. Bagley, Prof. P. G. H Boswell, D.Sc., D.I.C., F. W. Branson, F.I.C., Prof. J. W. Cobb, C.B.E., B.Sc., F.I.C., J. E. Foxon, Congreve Jackson, S. W. Morrison, O.B.E., Harry J. Powell, B.A., Col. C. W. Thomas, M. W. Travers, D.Sc., F.R.S., F.I.C., and H. S. Williams-Thomas.

Ordinary Members of Council: M. Asquith, F. J. Boam, W. R. Barker, R. S. Biram, W. Butler, F. G. Clark, J. Connolly, S. English, M.Sc., A.I.C., Thos. Davidson, Prof. W. G. Fearnsides, M.A., W. J. Rees, F.I.C., Stephen Shaw, F. Swann, W. W. Warren, and Duncan Webb (jun.).

Treasurer: F. Sweeting.

Secretary: W. E. S. Turner, O.B.E., D.Sc., M.Sc.

Assistant Secretary: C. J. Peddle, M.Sc., F.I.C.

Auditors: G. Wilson Clarke and Frederick Lax.

As three of the Council vacancies were due to death or premature retirement of members, a subsidiary ballot was held, as the result of which Prof. J. W. Cobb was elected a Vice-President to take the place of the late Sir Wm. Crookes, holding office, therefore, for one year only, Mr. F. W. Branson was elected to fill the place vacated by Mr. S. N. Jenkinson, and retires, therefore, in 1921; whilst Mr. Milton Asquith was elected to fill the vacancy due to the resignation of Mr. J. W. French, B.Sc., and will retire, therefore, in 1920.

Votes of thanks were passed to the retiring officers for their services.

At 3.15 an important discussion was initiated on "Scientific Research and the Glass Industry," by the retiring President, Mr. W. F. J. Wood, who gave an account of the steps which had been taken towards the formation of a Glass Research Association.

The following addresses were then delivered:—

"Industrial Research in the United States," by A. P. M. Fleming, O.B.E., M.I.E.E., illustrated by lantern-slides.

"State Aid for Scientific Research in the Glass Industry," by Sir Frank Heath, K.C.B.

After an interval for tea, an address was given by Dr. W. E. S. Turner on "The Future Welfare of the Glass Industry as Dependent on Scientific Effort."

During the course of the morning a visit of inspection was paid to the Department of Glass Technology, and demonstrations were carried out on the casting of a 2 cwt. glass pot by the members of the staff, and of the vacuum casting of a 38-inch covered pot by Mr. B. J. Allen.

The following new members were elected:—

Ordinary Membership.

Lothner, E. R.	Pukeberg, Nybro, Sweden.
Ostlund, K. E.	Hogbergsgatan, 21, Stockholm, Sweden.
Kjeugren, S.	Rejmyra, Sweden.
Butler, W.	Messrs. Icknield Glassworks, Freeth St., Birmingham.
Gass, G. P.	418, Manchester Road, Bolton.
Pearson, Samuel.	Charles St., West Bromwich.
Kirkpatrick, F. A., M.S.	Bureau of Standards, 40th and Butler Streets, Pittsburgh, Pa.
Fogelberg, C. G.	Kosta, Sweden.
Bunce, A., A.C.G.I.	Messrs. Cannington Shaw and Co., Ltd., St. Helens.
Davis, D. H	Pacific Coast Glass Co., San Francisco.
Taylor, W. C.	Corning Glass Works, Corning, New York.
Loomis, G. A.	Corning Glass Works, Corning, New York.
Shelly, F.	13, Rolleston Road, Burton-on-Trent.
Giles, Capt. A. S., M.C.	Messrs. J. Stevens and Son, Dartmouth St., Birmingham.
Firth, Miss E. M., B.Sc.	Dept. of Glass Technology, The University, Sheffield.
Middleton, G. G.	7, Highland Grove, Worksop.

In the evening the First Annual Dinner of the Society was held, the following guests and members being present:—

Guests.

Wood, W. F. J. (retiring President of the Society).

Ainger, R. (Commercial Editor of the *Sheffield Independent*).

Bradley, F. E., M.A., M.Com., LL.D., F.R.S.E. (jointly representing the Worshipful Company of Glaziers).

Gibbons, W. M., M.A. (Secretary of the Glass Research Delegacy).

Heath, Sir Frank, K.C.B., B.A., Ph.D. (Secretary of the Department of Scientific and Industrial Research).

Ripper, Prof. W., C.H., D.Eng., D.Sc., M.Inst.C.E., J.P. (Vice-Chancellor of the University of Sheffield).

Sparks, T. Mortimore (Commercial Editor of the *Sheffield Daily Telegraph*).

Tippetts, W. B. (Clerk to the Worshipful Company of Glaziers).

Trotter, A. P., M.Inst.C.E., M.I.M.E., M.I.E.E. (President of the Society of Illuminating Engineers).

Members and Friends.

Allen, B. J.
Ames, R. Y.
Asquith, H. H.
Barclay, W. R., A.M.I.E.
Barclay, Mrs.
Bateson, H. A.
Boam, F. J.
Bunnis, H.
Burdin, —
Butler, W.
Cauwood, J. D., M.Sc., A.I.C.
Chief Reporter, *Sheffield Telegraph.*
Clark, F. G.
Clarke, Capt. J. R., M.Sc.
Clark, Noel.
Clarke, W. B.
Connolly, Mr. and Mrs. J.
Davidson, J. H., M.Sc., F.I.C.
Dimbleby, Miss V., B.Sc.
Dowse, G.
Dryden, H. D.
English, S., M.Sc., A.I.C.
Firth, Miss E. M., B.Sc.
Fox, J. C.
Foxon, J. E.
Gardner, W. J.
Giles, Capt. A. S., M.C.
Heckels, J. S.
Hodkin, F. W., B.Sc., A.I.C.
Jackson, Miss A. M., B.Sc.
Kitson, J. B.
Lamplough, F. E., M.A.
McCormick, J.
Martin, W., M.A., M.D.
Morton, E.
Muirhead, Miss C. M. M., B.Sc.
Peddle, C. J., M.Sc., F.I.C.
Rees, W. J., F.I.C.
Rees, Mrs.
Sinkinson, E., D.I.C.
Smart, G. W., and guest.
Styring, J. B.
Thomas, Col. C. W.
Thomson, R. H.
Tinkler, W.
Trewartha-James, W. H., M.I.M.E., M.I.M.M., M.C.M.I.
Turner, W. E. S., O.B.E., D.Sc., M.Sc.
Turner, Mrs.
Wainwright, F. P.
Watkins, —
Watts, J. W.
Webb, Duncan, Jun.
Wood, Capt. Alphonse, M.I.C.E.
Wood, T. E., M.A., LL.B.
Wood, W. L. R., M.B.

The following toasts were rendered:—

(1) "The King," by the Chairman (Mr. J. Connolly).

(2) "The Society of Glass Technology," coupled with the name of Mr. W. F. J. Wood, C.B.E., B.Sc., F.I.C., retiring President. Proposed by Mr. J. Connolly.

(3) "The Guests." Proposed by Dr. W. E. S. Turner, O.B.E.

(4) "The Secretary." Proposed by Sir Frank Heath, K.C.B.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING.

Held in the Rooms of the Institute of Chemistry, 30, Russell Square, London, W.C.2, on Wednesday, May 21st, at 3.0 p.m., Dr. M. W. Travers, F.R.S., Vice-President, in the Chair.

The Chairman announced that the Council had had under consideration a report from the Publications Committee on the desirability of providing works of reference for the glass industry. The scheme which had found favour with the Council was one that involved publication of a comprehensive work under the auspices of the Society itself. A large capital outlay would be involved, however, if the scheme were adopted, and the Council considered it wise to submit the report to every member with the view of ascertaining the measure of support it was likely to receive. Accordingly, the report would be circulated and opinions invited.

A lecture, illustrated by a lantern demonstration, was next delivered by Dr. W. Rosenhain, F.R.S., entitled "Some Phenomena of Pot Attack."

Messrs. C. J. Peddle, Duncan Webb, jun., Arnold Stevenson, and the Chairman took part in the subsequent discussion, whilst Dr. Rosenhain replied.

During the morning a visit was paid by some of the members to the Glass, Optical, Metallurgical, Naval, and Experimental Aircraft Department of the National Physical Laboratory, Teddington, and a hearty vote of thanks was passed to the Director, Sir Richard Glazebrook, F.R.S., for his invitation, and to Dr. Rosenhain and Mr. E. A. Coad-Pryor for conducting the party through the various departments.

A cordial vote of thanks was also passed to the Council of the Institute of Chemistry for its kindness in providing accommodation for the meeting.

The following members were elected:—

Collective Member.

Bausch and Lomb Optical Co., Rochester, New York, U.S,A. Messrs.

Ordinary Members.

Frink, R. L.	The Frink Laboratories, Lancaster, Ohio, U.S.A.
Montgomery, R. J.	Bausch and Lomb Optical Co., Rochester, New York, U.S.A.
Baillie, W. L.	Directorate of Chemical Inspection, Wellesley House, Red Lion Lane, London, S.E.18.
Warthen, J. A.	American Bottle Co., Newark, Ohio, U.S.A.
Wilzin, A.	100 Bd. Victor Hugo, St. Ouen, France.

Student Members.

Butterworth, Lionel.	Messrs. Butterworth Bros., Newton Heath Flint Glass Works, Manchester (student Dept. of Glass Technology, University, Sheffield).
Turner, Stanley.	Stoneleigh, South Anston (student Dept. of Glass Technology, Sheffield).

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING.

Held at The University, Western Bank, Sheffield, at 3.0 p.m. on Wednesday, June 18th, the President, Mr. S. N. Jenkinson, in the Chair.

The President announced that a new Committee had been set up by the Council, termed "The Glass Standards Committee," and that its three sub-committees would welcome the assistance of all members of the Society in gathering information and arriving at just conclusions in connection with its work.

The Council had also received an invitation from the Glass Division of the American Ceramic Society to visit America in the late summer of 1920, and the President announced that the invitation had gladly been accepted. Notices concerning the arrangements would be circulated to members from time to time.

After the President had announced the death of Mr. J. H. Crowther, one of the original members of the Society, Dr. Turner paid a tribute to the enthusiastic work of Mr. Crowther, both in regard to technical education in the glass industry and to the interest he displayed in the work of the Society. A vote of condolence was passed to Mrs. Crowther and her son, the members signifying their approval by standing.

The President delivered an address on the aims and objects of the Society, and followed this address by an account of the position of the German glass industry as he found it in March, 1919.

The following papers were read:—

"Some Experiments with a Gas Fired Pot Furnace," by Dr. M. W. Travers, F.R.S.

"The Properties of British Fireclays Suitable for Glass Works Use," by Miss E. M. Firth, B.Sc., F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

In the discussion which followed, Prof. Fearnsides, Mr. W. J. Rees, Mr. F. G. Clark, Dr. M. W. Travers, and Dr. W. E. S. Turner took part.

The following members were elected:—

Ordinary Members.

W. M. Anderson.	The Capstan Glass Co., Connellsville. Pa., U.S.A.
H. C. Arnold.	North Avenue, Washington, Pa., U.S.A.
Wilbur F. Brown, A.B.	The Libbey Owens Sheet Glass Co., Charleston, W.Va., U.S.A.
G. F. Dufour.	c/o Schneider & Co., 21E 40th Street, New York City, U.S.A.
F. W. Hodkin, B.Sc.	A.I.C. Dept. of Glass Technology, The University, Sheffield.
Prof. A. Silverman.	The University of Pittsburgh, School of Chemistry, Pittsburgh, U.S.A.
G. L. Thomson.	The Manor House, Effingham, Surrey.

OBITUARY.

We very much regret to record the loss of

Sir Wm. Crookes, O.M., D.Sc., LL.D., F.R.S., Vice-President of the Society.

Sir William Crookes passed away on April 4th in his eighty-seventh year. His connection with the Society began at the very close of his singularly fruitful life, in which he had enriched science in many branches by discoveries of an exceedingly important character. Both his acute powers of observation and his wonderful skill as an experimenter continually kept him in the position of a pioneer, particularly in those branches of science where physics and chemistry are closely allied. In his hands the use of the spectroscope became one of the most valuable instruments which the chemist possesses, and by its aid he was successful in elucidating many problems connected with the so-called rare elements, some of which are now important commercial products. It would be difficult, indeed, in a short notice of this character even to refer to the chief objects of his energies. He was interested in distinctly practical subjects as well as those which lay more in the domain of chemical theory, and, amongst others, dealt with the subjects of the world's wheat supplies, water purification and examination, the treatment of sewage, dyeing, and the disinfection of cattle in disease, and his authority and eminence were recognised by the large number of universities which conferred on him their honorary doctorates, and by the numerous foreign societies which were themselves honoured by adding his name to their list of honorary members.

He will be specially remembered in the glass industry for his work on eye-preserving glasses for spectacles. The researches of Sir William in this direction were undertaken after he had passed his eightieth year, the results being published at the end of 1914. The object of the research was to obtain a glass which would shield and preserve the eyes of furnace operators from certain of the rays of light given off by the furnace. In this connection, he visited the works of Messrs

Nuttall at St. Helens, and Mr. Dixon-Nuttall has informed the writer that Sir William was there on several occasions, where he was provided with a dark-room in order that he might develop the plates after his series of spectroscopic photographs of the light given off from the molten glass. Once or twice he spent Saturday afternoon and evening late into the night at the works, and was there again on the Sunday morning, in the endeavour to complete his measurements.

Sir William was never able to attend a meeting of the Society owing to the state of his health, but the Secretary received several communications from him which indicated his interest in its work.

Mr. J. H. Crowther, manager of Messrs. R. Waddington and Sons, Mexborough, and of Messrs. Turner's Glass Co., Ltd., Worksop.

Mr. Crowther, who died on May 31st, at the age of fifty-two, was one of the original members of the Society. More than that, he knew of the project for some time in advance of the initial meeting, for it was his enthusiasm which in a very great measure helped in his own district to stimulate the interest of manufacturers and men in the subject of the application of science to the glass industry. It was, indeed, Mr. Crowther who first brought the writer into contact with the industry, for he brought the first questions concerning difficulties in glass making to the notice of the University of Sheffield Scientific Advisory Committee, of which the writer was Secretary, and a few months later he invited the writer to his home in Mexborough to meet a number of the local Trade Union leaders to discuss what could be done to form classes of instruction for the workers. With the enthusiastic help of Mr. Crowther, the first class was formed in Mexborough, and throughout the three and a-half years which followed he was the faithful shepherd, or perhaps father, of all the students in that neighbourhood. Although his early education had been but scanty, he himself, as a member of the classes, achieved success by sheer hard work, and his constancy and his enthusiasm were a joy and inspiration to his teachers.

By his fellow-students and associates a small fund has been inaugurated to establish a prize, called the Crowther Prize, to be awarded to the most successful student each year who attends the Saturday or evening courses in glass technology held at any centre under the auspices of the Sheffield scheme.

THE COMMITTEE FOR THE STANDARDISATION OF GLASS AND GLASSWARE.

In order to assist the industry during the period of reconstruction to obtain knowledge both of the best compositions and the best dimensions and shapes of various types of glassware, the Council has set up a Committee called the "Committee for the Standardisation of Glass and Glassware."

The Committee in the first instance consisted of Messrs. G. E. Alexander, M. Asquith, F. W. Branson, F. G. Clark, J. Connolly, S. W. Morrison, C. J. Peddle, W. J. Rees, Dr. M. W. Travers, W. F. J. Wood, with the President and the Secretary.

This Committee has held one meeting, at which it was resolved that three sub-committees should be set up as follows:—

Committee on Optical Glass.—Messrs. S. W. Morrison, C. J. Peddle, W. J. Rees, the President, and the Secretary.

Committee on Glass for Lamp-working Purposes.—Mr. F. W. Branson, Dr. M. W. Travers, the President, and the Secretary.

Committee on Bottle Glass and Glass Bottles.—Messrs. G. E. Alexander, M. Asquith, F. G. Clark, J. Connolly, the President, and the Secretary.

Each of the sub-committees has power to co-opt members. Miss V. Dimbleby, B.Sc., has accordingly been co-opted a member of the sub-committee on Bottle Glass and Glass Bottles.

The work of the committee on Optical Glass will, it is expected, be conducted mainly in co-operation with the Optical Society and the Optical Society of America.

Each of the other two committees has already set to work. These committees appeal to manufacturers and others to assist in the work by forwarding specimens and information.

In the case of the glass for lamp-working purposes, specimens of all types of glass tubing are desired, with a statement as far as possible of the source from which the specimen was derived, and any information about its lamp-working properties.

Manufacturers of glass bottles are invited to send average samples, about two dozen in number, of different types of glass bottles or containers, with information about the method of manufacture, including the composition, if the manufacturer is willing to give it. All the information obtained will be put at the disposal of the manufacturer who sends the bottles, and any information given by him on the subject of the batch composition will be treated in confidence.

REPORT OF THE COMMITTEE ON THE STANDARDISATION OF LABORATORY GLASSWARE.

[The following Report has been received from the Committee on which the Society of Glass Technology had a representative.]

The suggestion that the Society of Chemical Industry should take up the question of the standardisation of laboratory glassware was made on the occasion of the reading of a paper on "Scientific Glassware" by Dr. Morris Travers at the Annual General Meeting of the Society at Bristol in July, 1918 (see *Journal of the Society of Chemical Industry*, Vol. **37**, p. 235 T). Dr. Travers subsequently brought the matter before the British Chemical Ware Manufacturers' Association, which approved of the suggestion that the Society should take the initiative in the matter and assured Dr. Travers of its heartiest co-operation. A letter was received later from the Controller of Optical Munitions and Glassware Supply of the Ministry of Munitions, supporting the suggestion that standardisation should be effected as early as possible, and offering the services of a member of his technical staff to discuss the best methods of procedure to be adopted. On October 21st, 1918, Mr. F. W. Branson, of Messrs. Reynolds and Branson, Ltd., of Leeds, read a paper on "Some Aspects of the Chemical Glassware Industry" (including Standardisation), before the Yorkshire Section of the Society. (See *J.S.C.I.*, Vol. **37**, p. 337 T.)

At the meeting of Council of the Society held on October 24th, the President proposed that a committee should be appointed to confer with other interested bodies on the subject, with a view to cutting down the supply of various classes of apparatus to a certain number of standard sizes, and he intimated that the Société de Chimie Industrielle was prepared to co-operate in the matter. This proposal was agreed to, and the following were appointed to serve on the Committee:—Sir Robert Hadfield, Mr. K. Chance, Sir Herbert Jackson, Dr. C. Carpenter, Mr. W. F. Reid, Dr. Travers (convener), with the President (Prof. Louis) and the Hon. Treasurer (Mr. D. Lloyd Howard) *ex officio*.

At the first meeting of the Committee, held on November 20th, the subject was discussed in a preliminary manner, and it was strongly felt by the members present that it was necessary in the first instance to obtain the views of manufacturers, users, and the retail trade. The Committee therefore asked the Council to authorise it to obtain the co-operation of representatives of these bodies, and the Council at its meeting in November authorised the Committee to co-opt other members and to call in the assistance of associations or individuals at its discretion. The Committee, acting on this authority, has since co-opted the following members:—Mr. Arnold Stevenson (Glassware Supply, Ministry of Munitions), Mr. V. Stott (National Physical Laboratory), Dr. J. J. Fox (Government Laboratory), Mr. J. R. Griffin (British Laboratory Ware Association), Mr. F. W. Branson of Leeds, Mr. D. P. Berridge and Mr. F. A. Beesley (Science Masters' Association), Mr. G. F. Baker (British Lamp-blown Scientific Glassware Manufacturers' Association), Dr. S. Rideal (Society of Public Analysts), Mr. T. A. Moore (India Office), Mr. G. A. Mallinson, interim (Pharmaceutical Society), Dr. W. E. S. Turner (Society of Glass Technology), Lt.-Col. D. Harvey (War Office). Mr. Kenneth M. Chance, owing to business engagements, has had to resign his membership of the Committee.

In dealing with each class of apparatus the Committee in the first instance set to work to collect information as to the varieties and sizes manufactured before and during the war, and statistics of sales by the distributing firms, which gave the only definite indication of the relative demand for different articles. In the case of beakers the Committee also endeavoured to obtain the views of users as to the forms and sizes which should be manufactured, by addressing an inquiry to certain of the more important professional bodies, but the answers which they received were so indefinite that the method was not followed up As it frequently happened that important information with regard to a particular kind of glassware was received when the inquiry relating to it appeared to have almost reached a conclusion, the work of the Committee has been somewhat prolonged.

In making its recommendations the Committee has had due regard for the fact that much money had already been spent on moulds, and that it would be quite useless to advise the manufacturers to replace existing moulds by new ones, without very strong reasons for doing so.

All dimensions and capacities are given in metric measure, which the Committee considers should be more uniformly adopted. This point is important, if an export trade in scientific glassware is to develop in connexion with such countries as South America.

CYLINDRICAL BEAKERS.

The study of the problems connected with this section of the subject occupied a considerable amount of time. Detailed information as to the sizes manufactured by British, German, and Austrian houses was laid before the Committee, and also statistics as to the relative numbers of the various sizes of beakers sold by the principal dealers in this country. Every endeavour was made to ascertain the views of users as to the forms and sizes of beakers most commonly employed in scientific and analytical laboratories. Suggestions made by both manufacturers and dealers with a view to cheapening production and distribution had also to be considered.

So extensive was the information which was ultimately collected that it was necessary to appoint a Sub-Committee to deal with it. On the report of the Sub-Committee the Committee decided to make certain definite recommendations which are detailed below:—

It appeared that three kinds of beakers were on the market:—(*a*) A squat form with or without spout, (*b*) a medium form, (*c*) a tall form. It was generally agreed that two forms would meet all requirements.

The thicknesses of the walls of beakers should approximate to those set down in the table. It was decided that no advantage is to be gained by specifying as the nominal capacity of a beaker the approximate content when filled to a definite distance from the top, because in analytical practice a beaker is usually half filled with liquid, but that the capacity of a beaker should be specified as the approximate content when filled to the brim with liquid. The total height, and the external diameter immediately above the curve at the base should also be catalogued. From the point of view of the user the taper in beakers should be slight, otherwise precipitates tend to settle on the walls; a slight taper is also desirable from the manufacturing point of view, so that the article when blown may be easily freed from the mould. For storage purposes the tapering of beakers is an advantage, for the greater the taper, the greater is the number of beakers of a single size which can be stored in a bin. It was decided that a taper of 1 in 20 on the diameter should be adopted.

From the manufacturing point of view it is important that the series of beakers should be so designed that corresponding numbers of the squat and tall beaker series should have identical diameters at the base, so that a tall beaker spoiled in the process of manufacture could be cut down to the height of the squat beaker. This principle, which had been employed by Bohemian manufacturers and by one English firm, was adopted by the Committee.

While it was of equal advantage to manufacturers, dealers, and users, to reduce the number of beakers in the series, in arriving at a decision as to the series which should be adopted, close attention had to be paid to the following points:—

(*a*) The series must contain those sizes which are in most common use. (*b*) The space between the beakers must be such as to allow of packing material being placed between adjacent members when the beakers are nested. The space between the beakers must increase with increase in diameters of the beakers. (*c*) When the beakers are nested the rim of each beaker must rest on the rim of the next in series. (*d*) The general appearance of the beakers when nested in series must not be left out of account.

It was finally decided to adopt the following series of diameters:—26, 30, 35, 41, 48, 56, 65, 75, 86, 98, 111, 125, 140, 156, 173 mm.

Finally, the ratio of the height to the diameter of the beakers in the two series was considered, and after reviewing the information which had been collected with regard to existing series, it was decided to adopt the values 1·37 and 2·0 as the values of the ratio, overall height to diameter near base, for squat and tall series respectively.

TALL SERIES.

Ratio $\frac{\text{Height}}{\text{Diam.}} = \frac{2}{1}$ Taper = 1 in 20.

A	B	C	D	E	
No.	External diam. near base, mm.	Thickness of walls, mm.	Overall height, mm.	Approximate capacity to level of brim, c.c.	No.
0	26	0·5	52	25	0
1	30	0·5	60	40	1
2	35	0·5	70	60	2
3	41	0·5	82	100	3
4	48	0·75	96	160	4
5	56	0·75	112	250	5
6	65	0·75	130	400	6
7	75	0·75	150	600	7
8	86	1·00	172	1000	8
9	98	1·00	196	1500	9
10	111	1·00	222	2000	10
11	125	1·00	250	3000	11
12	140	1·25	280	4000	12
13	156	1·25	312	6000	13

SQUAT SERIES.

Ratio $\frac{\text{Height}}{\text{Diam.}} = 1{\cdot}37$ to 1. Taper = 1 in 20.

A No.	B External diam. near base, mm.	C Thickness of walls, mm.	D Overall height, mm.	E Approximate capacity to level of spout, c.c.	No.
1	30	0·5	41	25	1
2	35	0·5	48	40	2
3	41	0·5	56	60	3
4	48	0·75	66	100	4
5	56	0·75	77	160	5
6	65	0·75	89	250	6
7	75	0·75	103	400	7
8	86	1·0	118	600	8
9	98	1·0	134	900	9
10	111	1·0	152	1300	10
11	125	1·0	171	2000	11
12	140	1·25	192	2750	12
13	156	1·25	214	4000	13
14	173	1·25	237	5000	14

The preceding tables give the dimensions of two series of beakers recommended for adoption by the Committee. It is also recommended that the data set down in columns A, B, D, and E be given in price lists and catalogues.

Beaker Flasks and Conical Beakers.

It appeared to the Committee that no advantage would be gained by suggesting that manufacturers should make new moulds for beaker flasks and conical beakers. It recommends, however, that the greatest diameters, the heights, and the total capacities of these articles should be catalogued.

FLASKS.

The Committee considers that a flask should hold at least the nominal capacity when filled with liquid to the level of the base of the neck. The nominal capacity and the external diameter of the neck should be catalogued.

The flange of a flask should be turned over sharply, the mouth should not be belled.

It did not appear to the Committee that any material advantage was to be gained by reducing the number of round and flat-bottomed flasks manufactured, except in so far as it might be possible to eliminate one or the other of almost identical sizes such as those corresponding to 100 and 125 c.c., 350 and 400 c.c.; 700 and 750 c.c., 1250 and 1300 c.c. The sizes of flasks between 50 and 10,000 c.c., which it considers to be sufficient to meet all requirements, are set down in the following table. Of these flasks, those corresponding to 600, 1250, and 2500 c.c. are retained, as they correspond to the pint, quart, and the 2 quart sizes, and are therefore in demand for certain purposes.

It was suggested to the Committee that if flasks, over a considerable range, had necks of the same diameter, the number of sizes of rubber stoppers which it would be necessary to stock in the laboratory might be considerably reduced. The Committee decided not to adopt the suggestion.

The Committee recommends that as new moulds come to be made, the necks should conform to the following dimensions:—

(*a*) FLAT, ROUND-BOTTOMED AND CONICAL FLASKS.

Capacity of flask, c.c.	External diameter of neck, mm.	Capacity of flask, c.c.	External diameter of neck, mm.
50	17	(1250)*	33
100	18	1500	35
150	18	2000	40
200	21	(2500)*	40
250	25	3000	45
350	25	4000*	45
500	27	5000	55
(600)*	27	7500	60
750	29	10,000	65
1000	33		

* Flat and round-bottomed only.

It appears that there is still a demand for the pear-shaped as well as the globular form of flask.

(*b*) WIDE-MOUTHED FLASKS WITH SHORT NECKS.

i. Flat-bottomed flasks, known as CO_2 flasks or extraction flasks.
ii. Round-bottomed flasks, known as bolt heads.

Capacity, c.c.	Diameter of neck, mm.	Capacity, c.c.	Diameter of neck, mm.
50	30	750	50
100	35	1000	55
150	35	1500	55
250	40	2000	60
350	40	3000	60
500	45	5000	65

Flat-bottomed flasks to 500 c.c. capacity only.

In view of the fact that a very considerable number of moulds for the short, wide-mouthed flasks, with flat and round bottoms (known as extraction or CO_2-flasks, and bolt-head flasks respectively), are already in the hands of various manufacturers, the Committee suggests that the manufacturers should confer amongst themselves with a view to eliminating unnecessary sizes at once.

(*c*) DISTILLATION FLASKS.

Capacity, c.c.	Diameter of neck, mm.	Length of neck, mm.
50	12	135
100	15	145
150	17	155
250	20	170
350	20	185
500	23	200

Larger sizes as round-bottomed flasks.

(*d*) KJELDAHL FLASKS.

Capacity, c.c.	Diameter of neck, mm.	Capacity, c.c.	Diameter of neck, mm.
100	22	300	28
200	25	500	30

(*e*) CONICAL FILTERING FLASKS.

The flasks must be well annealed, evenly blown, and thick in the walls, so as to be able to stand exhaustion, and filling with boiling liquid without cracking. The neck of filtering flasks to take rubber stoppers should be turned out sharply and not belled. The tubulure should be so drawn out as to take thick-walled rubber tube 3/16-in. internal diameter. The internal diameter of the neck should be at least:—

Capacity, c.c.	Diameter, mm.	Capacity, c.c.	Diameter, mm.
100	25	1500	40
250 or 300	33	2000	45
500	35	3000	45
750	40	5000	50
1000	40		

KIPP'S APPARATUS.

The overall height and the diameter of the middle bulb should be listed.

The Committee considers that four sizes corresponding to 85 mm., 105 mm., 125 mm., and 180 mm.; or 250, 500, 1000, and 2000 c.c. should meet all requirements.

FUNNELS.

(*a*) Plain or Fluted Funnels of Thin Glass.

It is of very great importance that funnels should be made so that, in the case of plain funnels, a hardwood cone accurately turned to an angle of 60° will fit into the inside without side play. In the case of ribbed funnels the ribs should be pronounced on the inside.

Funnels should be ground flat on the top.

The stems should either be of parallel bore, or should taper slightly to the point; taper in the reverse direction is objectionable. The point should be ground off at an angle of about 30°.

Though the sizes of funnels are generally catalogued in inches, the Committee suggests that the dimensions should in future be given in millimetres. The series 1, 1½, 2, 2½, 3, 3½, 4, 4½, 5, 6, 8, 10, 12 inches, should be replaced by the series 30, 45, 60, 75, 90, 105, 125, 150, 200, 250, and 300 mm., the number in the series being reduced from 13 to 11, the sizes 3, 3½, and 4 in., which are important, corresponding almost exactly with the sizes 75, 90, and 105 mm.

The following is a summary of the suggested dimensions of funnels:—

Outside diameter across top, mm.	Approximate length of stem, mm.	Approximate external diameter of stem, mm.
30	45	5
45	60	5 to 6
60	75	6 to 8
75	90	8 to 10
90	105	8 to 10
105	120	10 to 12
125	130	10 to 12
150	150	12 to 15
200	165	15 to 20
250	180	20 to 23
300	200	22 to 25

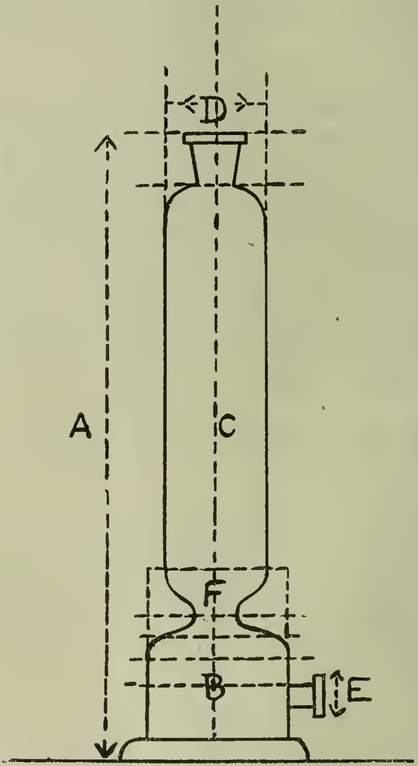
(*b*) Deeply Ribbed Funnels, Pressed.

The following sizes, for which press moulds already exist, were adopted by the Committee:—

7, 9, 11, and 16 cm.

DRYING TOWERS.

The total height and the diameter of the Cylindrical portion should be catalogued. The tubulure at the base should not be less than 15 mm. in diameter at the outer end. The following dimensions of drying towers—from moulds which already exist—are recommended for adoption:—



No.	A	B	C	D	E	F
1	200	45	40	25	15	15
2	250	55	45	30	15	18
3	300	65	50	30	15	18
4	400	90	65	30	15	22

It is important that the internal diameter of the constriction should be less than the minimum internal diameter of the neck.

DESICCATORS.

The catalogued dimension of a desiccator should be the internal diameter of the opening of the container portion of the apparatus.

The dimensions of a desiccator should be such that the depth of the part of the apparatus in which the article or material to be dried is placed should be at least two-thirds of the diameter of the opening.

The ground contact surface between the body of the apparatus and the lid or cover should be at least 15 mm. for 100, 125, and 150 mm. sizes, and 20 mm. for 200 and 250 mm. sizes. In the case of vacuum desiccators, the ground contact surface should not be less than 20 mm. in any case.

The Committee considers that the following variety and sizes of desiccators will meet all requirements:—

Scheibler form (plain, with tubulure in lid, and with tubulure in side), 100, 125, 150, 200, and 250 mm.; Fresenius form, 125 mm.; Hempel form, 150 mm.

ASPIRATORS and WOULFE'S BOTTLES.

The Committee recommends that the diameter and height overall be listed. The vessel should contain at least its nominal volume when filled with liquid to the base of the neck.

The ratio of the diameter to the height to the base of the neck should not be less than 3 to 5.

The taper of the necks and tubulures should be such as to correspond to change in diameter at a rate corresponding to about 1 in 7, so as to allow of stoppering, and to fit corks and rubber stoppers.

In the case of Woulfe's bottles, it is important that the side necks be so placed that a glass tube can pass through the centre of a cork in the neck vertically to the bottom of the bottle.

It is considered that the following sizes will meet all requirements:—

Nominal capacity, c.c.	Minimum internal diameter of necks, mm.	Minimum internal diameter of tubulures, mm.
125*	15	15
250	15	15
500	20	15
1000	25	20
2500	32	20
5000	40	25
7500	40	25
10,000	40	25
15,000	45	25

* Woulfe's bottle only

GRADUATED APPARATUS.

The Committee desires to call attention to the facilities offered by the National Physical Laboratory for the testing of graduated glassware. The Committee has had before it copies of a pamphlet dealing with "Volumetric Tests on Scientific Glassware" issued by the National Physical Laboratory in July, 1918, in which full information relating to the details of these tests is given. Copies of this publication may be obtained free of charge on application to The Director, The National Physical Laboratory, Teddington, Middlesex. The pamphlet deals with Class A Tests, that is, the examination of apparatus in which the highest degree of accuracy is required, and vessels which pass the tests have the Laboratory mark, which is a combination of the Laboratory monogram and the date of test, etched on them. Apparatus submitted for Class A Tests and found to be outside the limits of acceptance for standard apparatus is, if considered of reasonable accuracy for commercial purposes, given the Class B mark. In addition to the Class A tests the Laboratory has now under consideration Class B tests, that is, the examination of apparatus primarily intended to possess only commercial accuracy. It is hoped that it may be possible to complete the final arrangement for these tests in the near future.

(*a*) Pipettes.

The dimensions recommended for single-mark bulb pipettes are given on the next page.

In view of the great divergence in opinion and practice amongst chemists in their methods of using pipettes and burettes it was thought desirable to include in this report brief notes on this subject.

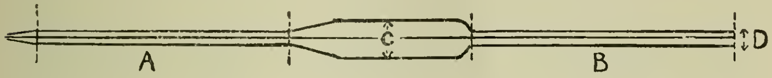
With regard to pipettes, numerous methods of using one mark delivery pipettes have been proposed from time to time; but all may be included in one or other of the two following classes:—

(*a*) Those in which the small quantity of liquid which remains in the jet is allowed to stay there, and

(*b*) Those in which this liquid is ejected, *e.g.*, by blowing down the pipette, or by closing the top of the pipette with one finger and warming the bulb by clasping it with the other hand.

Methods in which the small quantity of liquid which collects in the jet of a pipette when outflow has ceased is allowed to remain there are more reliable than those involving the ejection of this liquid. The latter methods are, therefore, not to be recommended.

With regard to the former methods it is essential in order to obtain the best results to have a perfectly definite order of procedure. Recommendations as to the procedure to be followed are given below. In order to obtain results with pipettes tested at the National Physical Laboratory which shall be in agreement with the values certified, the pipette should be used in accordance with the conditions of test printed on the certificate of corrections. In cases, however, where one is prepared to accept the nominal value of a pipette provided that it is correct within reasonable limits the following method may be used, with pipettes calibrated in accordance with the National Physical Laboratory methods of test, without introducing appreciable errors.



Capacity c.c.	1	2	4	5	10	25	50	75	100
A ... ... mm.	95	100	120	120	190	200	200	200	165
B ... ... mm.	110	115	120	120	160	200	200	200	200
C (int.) ... mm.	5·5 to 6·5	7 to 7·5	10 to 10·5	11·5 to 12	13·5 to 14	17 to 18	27 to 28	30 to 31	35 to 36
D (int.) ... mm.	2	2	3	3	4	5	5	5	7
Distance of mark above bulb, about mm.	25	35	35	35	40	50	50	50	50

The pipette is filled with liquid to a short distance above the mark. Liquid is then run out until the meniscus is on the mark and the outflow is then stopped. The drop adhering to the tip is removed by bringing the tip of the pipette into contact with the surface of the liquid from which it has been filled and then removing it without jerking. The pipette is then held vertically and allowed to deliver with the jet touching the side of the receiving vessel, the vessel being slightly inclined. The pipette is allowed to drain for 15 seconds after outflow has ceased, with the tip still in contact with the side of the vessel, and the pipette itself vertical. On completion of the draining time the vessel is removed from contact with the tip of the pipette, thus removing any drop adhering to the outside of the pipette. To determine the instant at which outflow ceases, the motion of the liquid surface down the delivery tube of the pipette is observed, and the delivery time is considered to be complete when the meniscus comes to rest slightly above the end of the delivery tube. The one-fourth minute draining time is counted from this moment.

The method just described in detail differs from the method of test at present employed at the National Physical Laboratory only in the following particulars:—

(*a*) The pipette is allowed to deliver with the jet continuously in contact with the walls of the receiving vessel instead of using free delivery.

(*b*) At the end of the one-fourth minute drainage time the drop adhering to the pipette is detached against the side of the receiving vessel instead of on the surface of the liquid already delivered.

As stated previously, when a pipette is being used for work in which, if the pipette is accurate within reasonable limits, it is sufficient to accept its nominal volume for delivery as the correct volume delivered, then it is immaterial whether the National Physical Laboratory method is adhered to strictly or the alternative method given above be used. The difference between the results obtained by the two methods is appreciably less than other possible incidental errors. This is assuming, of course, that the pipette was initially calibrated for the above methods of use. If, however, such a pipette is used by methods involving the ejection of the drop of liquid, which in the above methods is allowed to remain in the pipette, the results obtained may differ very appreciably from the volume delivered by the method for which it was calibrated. In view of the fact that more reliable results are obtainable by the methods of using pipettes described above than by injection methods, it is recommended that manufacturers should continue to calibrate pipettes in accordance with the conditions of test specified in the National Physical Laboratory test pamphlet previously referred to. Further, in order to secure uniformity of results it is desirable that users of pipettes should follow the above recommendations as to method of use. In arriving at the conclusions set out above the results of a recent investigation on different methods of using pipettes carried out at the National Physical Laboratory were available to the Committee, and will be published in the near future.

BURETTES.

Two of the main sources of error in the use of burettes are:—

(*a*) Change in rate of delivery arising from different manipulation of the tap on different occasions. This causes a variation in the volume of liquid delivered corresponding to a given interval on the burette. (*b*) Change in reading due to drainage of liquid down the walls of the burette.

Quite large errors may arise from these causes and often escape detection in ordinary analytical work, particularly if burettes with quick delivery times are used. By delivery time is meant the time occupied by the outflow of water from the zero graduation mark to the lowest graduation mark when the tap is fully open. The possibility of errors arising from the above causes is reduced to a very considerable extent by using burettes with comparatively long delivery times.

The times of delivery specified by the National Physical Laboratory for burettes submitted for Class A tests are given in table A.

TABLE A.

Length graduated, cm.	Minimum time of outflow, sec.	Maximum time of outflow, sec.
15	30	60
20	40	80
25	50	100
30	60	120
35	70	140
40	80	160
45	90	180
50	100	200
55	110	220
60	120	240
65	130	260
70	140	280
75	150	300

The minimum times of delivery have been so chosen that for tubes of the diameters ordinarily employed for burettes, the rise in the meniscus due to drainage shall not exceed approximately 0·05 mm. in the first two minutes after closing the tap. The maximum times have no physical significance, but merely fix an upper limit in order to avoid the rate of delivery being made intolerably slow.

With burettes conforming with the above limits as to delivery time, the second cause of error mentioned at the outset, viz., change in reading due to drainage, is practically eliminated. The errors introduced by increasing the time of delivery above the natural time of delivery of the burette are also very much smaller than would be the case with burettes calibrated for a quick delivery.

With burettes calibrated for the above delivery times the only demands made upon the user in order to obtain results in agreement with those obtained in testing the burette are:—

(1) The burette should be allowed to deliver with the tap fully

open. (2) The reading should be taken immediately after the required amount of liquid has been run from the burette. (3) The 0 c.c mark of the burette should be taken as the starting point.

The mode of manipulation is thus extremely simple, and makes a minimum demand on the user's time and attention.

It is worth while to consider the above details of manipulation more fully, with a view to possible variations in the course of analytical work.

The first condition should be adhered to as strictly as possible. If, however, the liquid is delivered more slowly, the errors introduced will be much smaller for burettes of the specified times of outflow than for burettes of short delivery time. Moreover, the times of delivery fixed are quite long enough for almost all purposes, and it will rarely be desired to lengthen them still further. It is, of course, not feasible to keep the tap fully open when the end-point of a titration is being approached. The fact that the last cubic centimetre or so is delivered quite slowly is in effect, however, simply an introduction of a short drainage time, and it has been pointed out previously that the delivery times have been so chosen that the rate of drainage is almost negligibly small. Also, in testing burettes the last cubic centimetre is necessarily run out slowly, thus approximating to the conditions of an actual titration. It may also be desirable at times to add the reagent from the burette in small quantities at a time. If this is done by smartly turning the tap fully open and smartly closing it when the required fraction has been added, the total volume thus added, as indicated by the initial and final burette readings, will be in close agreement with the volume delivered by emptying the burette continuously from the initial to the final reading. This again is in virtue of the fact that the delivery times have been chosen sufficiently long. With quick delivery times very different results would be obtained in the two cases. It should further be pointed out that although the proposed delivery times are appreciably longer than those which it is customary to employ, yet by eliminating the necessity of waiting for drainage, the time occupied by a titration is actually shortened in spite of the increased delivery time.

The second condition, given previously, that the reading should be taken immediately after the required amount of liquid has been taken from the burette, may be departed from within reasonable limits (say, two or even five minutes), to suit the convenience of the user. If the third condition is departed from and a reading other than the 0 c.c. mark is taken as the initial reading, only quite small errors will be introduced.

The Committee recommends that burettes should be made with delivery times in accordance with the National Physical Laboratory specifications and used in the manner described above.

The Committee recommends that a detailed account of the work of Mr. V. Stott on the use of pipettes and burettes shall be published in the Society's *Journal.**

MEASURING FLASKS.

The Committee calls attention to the dimensions of necks of graduated flasks set down in the pamphlet issued by the National Physical Laboratory.

MEASURING CYLINDERS.

The Committee calls attention to the fact that only in the case in which the body of a measuring cylinder is made from tube is it possible to obtain anything approaching perfect uniformity of internal diameter. In cylinders blown in the mould the internal diameter invariably diminishes more or less sharply towards the bottom, and the walls are often irregular. The length of the bottom of a cylinder blown in a mould corresponding to 1/10 of the nominal capacity should not be graduated, as the readings over this range are likely to be inaccurate.

In reading the level of liquid in measuring cylinders attention is called to the method of observation described by the National Physical Laboratory. Unless proper precautions are taken widely different results can be obtained.

The following dimensions of cylinders are recommended for general use:—

Capacity, c.c.	Diameter, mm.	Height overall, stoppered, mm.	Height overall, unstoppered, mm.	Diameter of foot, mm.
5	13	—	110	35
10	15	—	125	35
25	20	200	200	45
50	24	240	200	50
100	31	290	240	60
250	41	380	330	75
500	52	480	380	95
1000	67	510	440	115
2000	82	610	500	130

LAMP-BLOWN APPARATUS.

The Committee considered the possibility of standardising lamp-blown apparatus. It was represented to it that if such pieces of apparatus as the Orsat gas-analysis apparatus were standardised, chemists would not experience the difficulty of replacing broken parts which existed at the moment. The Committee, however, was not in a position to undertake the enormous amount of detailed work which the fixing of standards would entail, but suggests that the matter might be taken up by the British Lamp-blown Scientific Apparatus Manufacturers' Association. As no moulds are required in this work the case is somewhat different from that of the mould-blown hollow ware.

---

* *Journal of the Society of Chemical Industry.*

[Signed]
MORRIS TRAVERS, *Chairman.*
J. P. LONGSTAFF, *Secretary.*

July 12*th*, 1919.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING.

Held in the Lecture Room of the Coal, Gas, and Fuel Industries Department, The University, Leeds, on Wednesday, October 15th, at 3 p.m., Mr. S. N. Jenkinson, President, in the chair.

On the motion of the President, the thanks of the Society were tendered to Mr. J. H. Davidson for the careful attention he had given to the business of the Society in the absence of Dr. Turner.

The meeting was informed of a Circular Letter from the Ministry of Labour, copies being available for distribution among members.

The President announced that the Glass Research Association had been successfully launched, and he appealed for subscribing members.

A cable from America, signed by Dr. E. Ward Tillotson, Mr. Joseph Connolly, and Dr. W. E. S. Turner, was read to the meeting. It ran as follows:—"The Glass Division of the American Ceramic Society unites with us in sending heartiest greetings to President and Members of Society."

A paper was then read on behalf of Mr. J. S. Atkinson entitled, "Some Recent Improvements in the Design of Glass Works Furnaces and Gas Producers." The paper was illustrated by lantern slides. It was followed by considerable discussion, in which there took part Profs. Cobb and Fearnsides, Messrs. J. H. Davidson, F. Wood, W. J. Rees, R. L. Frink, T. W. Ferry, and the President, Mr. Atkinson replying.

Mr. Robert L. Frink, of Lancaster, Ohio, U.S.A., next read a paper entitled, "The Manufacture of Table Ware in Tank Furnaces." Prof. Cobb, Messrs. J. H. Davidson, W. J. Rees, C. J. Peddle, and the President took part in the discussion which followed.

A vote of thanks was passed to the Council of the University, Leeds, for its kindness in providing accommodation for the meeting.

The following members were elected:—

Collective Members.

Asahi Glass Co., Messrs., Ltd.	Tsurumi Factory, Tsurumi, nr. Yokohama, Japan.
Charbonneaux et Cie, Messrs.	Verreries de Reims, Reims, France.
Harvey Free, Messrs., Ltd.	15, Bateman Street, Dean Street, London, W. 1.

Robinson, Nelson & Co., Messrs.	378, City Road, Old Trafford, Manchester.
Saint Gobain, Cie de, Messrs.	Glaceries de la, 1bis Place des Saussaies, Paris.
Stevens, James & Son, Messrs.	Victoria Glass Works, Dartmouth Street, Birmingham.
Wiggin, H., & Co., Messrs., Ltd.	Wiggin Street Works, Birmingham.

Ordinary Members.

Adams, Irving E.	Federal Glass Co., Columbus, Ohio, U.S.A.
Barrows, H. H.	Oakland Mazda Lamp Division of General Electric Co., Oakland, Calif., U.S.A.
Claudon, Charles F.	824, Columbus Street, Ottawa, Illinois, U.S.A.
Coad-Pryor, E.A., B.A.	41, Coles Hill Road, Teddington, Middlesex.
Corbett, J. P.	8, Belmont Street, Mexborough.
Duncan, George S., M.A., B.Sc.	Dept. of Glass Technology, The University, Sheffield.
Graham, Albert	Manager, Pitney Glass Division, National Lamp Works, General Electric Co., Cleveland, Ohio, U.S.A.
Haig, Wilfred G.	9, Bowyer Road, Saltley, Birmingham.
Hess, H. W., B.S., M.S.	Libbey Glass Co., Toledo, Ohio, U.S.A.
Howes, H. W.	259, Springvale Road, Walkley, Sheffield.
Joseph, J.	50, Handen Road, Lee, London, S.E. 12.
Kaye, John, M.A., B.Sc., F.I.C.	Westerfield, Perth.
Kaye, Thomas	26, Rose Crescent, Perth.
Kelkar, G. D.	Dept. of Glass Technology, The University, Sheffield.
Kershaw, Lawrence H.	81, Ruskin Drive, St. Helens.
King, James Watt	Messrs. Dominion Glass Co., Ltd., Hamilton, Ontario, Canada.
McLeod, G.	The Dominion Glass Co., Ltd., Montreal, Canada.
O'Neill, Frank	The O'Neill Machine Co., Toledo, Ohio, U.S.A.
Paterson, C. C., O.B.E., M.I.C.E., M.I.E.E.	Research Laboratories of the General Electric Co., Osram Robertson Lamp Works, Hammersmith, London, W. 6.
Robertson, E. D. J.	Morningside, Kilmarnock.
Russell, Frank	Auldam House, Worksop.
Sharp, D. E.	Spencer Lens Co., Optical Glass Plant, Hamburg, N.Y., U.S.A.
Shibata, R.	Imperial Japanese Navy, Broadway Court, Broadway, Westminster, London, S.W. 1,
Stewart, James	10, Cornhill Terrace, Jeanfield, Perth.
Waite, Horatio T.	24, E. Oak Street, Newark, Ohio, U.S.A.
Walker, James Workman, Brigadier-General, C.M.G., D.S.O., J.P.	Castle Park, Irvine, Scotland.
West, Chas. H.	6323, Forbes Street, Pittsburgh, Pa., U.S.A.
Williams, Warren S., B.S.	Bureau of Standards, Pittsburgh, Pa., U.S.A.
Willmer, E. A. B., Lieut. R. E., A.M.I.C.E.	59, Ventnor Villas, Hove, Sussex.
Wise, Wilfred, B.Sc.	Field Cottage, Ashridge Vale, Chesham, Bucks.

Student Member.

Snowden, William C	24, Beaconsfield Street, Acomb, York.

PROCEEDINGS OF THE TWENTY-NINTH MEETING.

HELD in the Metallurgical Lecture Room, Applied Science Department, The University, St. George's Square, Sheffield, on Wednesday, November 19th, at 3 p.m. Dr. M. W. TRAVERS, F.R.S., Vice-President, in the chair.

The CHAIRMAN announced that in order to economise time at meetings and to give members an opportunity of scanning the list of applications for membership, the Council had decided that a printed list of applications would be issued prior to each meeting. Objection to the application of any firm or person could then be made either in writing or at the outset of the meeting when the list was put up for approval by the President or Chairman.

The CHAIRMAN, on behalf of the Society, welcomed Dr. Turner and Mr. Connolly on their return from America. Dr. TURNER and Mr. CONNOLLY, in replying, paid a tribute to the kindness they had received everywhere they had been in America. They strongly recommended members to join in the excursion planned for 1920.

Prof. COBB, C.B.E., B.Sc., F.I.C., then read a paper entitled, "The Reversible Expansion of Refractory Materials," by H. J. Hodsman, M.Sc., F.I.C., and himself. The paper was illustrated by lantern slides. Messrs. W. J. Rees, J. H. Davidson, W. J. Gardner, J. Holland, and the Chairman took part in the discussion that followed.

A paper entitled, "A Proposed Standard Formula for a Glass for Lampworkers," by F. W. Branson, F.I.C., and F. H. Branson, A.I.C., was then read by the former. The paper was illustrated by lantern slides and by specimens of glass. A discussion followed, to which Dr. Turner, Mr. F. W. Hodkin, and the Chairman contributed.

A vote of thanks was passed to the Committee of the Applied Science Department of the University, Sheffield, for its kindness in providing accommodation for the meeting.

The following members were elected:—

Collective Members.

Stein & Atkinson, Messrs., Ltd.	47, Victoria Street, Westminster, London, S.W. 1.
Taylor F. H. & Sons, Messrs.	131, Seven Sisters Road, London, N.

Ordinary Members.

Archer, Clodien	Directeur des Verreries de l'Etablissement de St. Galmier, Veauche, Loire, France.
Atkinson, James Stanley	66, Ashley Gardens, Westminster, London, S.W. 1.
Barton, Geo. E., B.Sc., M.Sc.	227, Pine Street, Millville, N.J., U.S.A.
Bliss, Edwin C.	Cumberland Glass Manufacturing Co., Bridgeton, N.J., U.S.A.
Chandorkar, R. D.	c/o Paisa Fund Glass Works, Talegaon (Dabhada), India.
Flint, Francis C., B.S.	331, So. Main Street, Washington, U.S.A.
Gleason, Marshall W.	864, Park Place, Brooklyn, N.Y., U.S.A.
Graham, Samuel	c/o Mrs. Collens, 23, Hatfield Street, Belfast.
Heuisler, Philip I., B.A., M.S.	Catonsville, Maryland, U.S.A.
Holland, J.	The Gables, Grindleford, nr. Sheffield.
Horsburgh, J. M.	139, Langsett Road, Sheffield.
Koering, Eustachius W., C.E.	Crystal Avenue, Vineland, N.J., U.S.A.
Koering, Louis	Durand-Koering Glass Co., Vineland, N.J., U.S.A.
Kopp, Nicholas	1529, Shady Avenue, Pittsburgh, Pa., U.S.A.
Martin, Edward Butler	Milford House, Brockley Grove, Brockley, London, S.E. 4.
Ogale, Gurunath P., L.M.E.	Department of Glass Technology, The University, Sheffield, and c/o Ogale Glass Works, Ogalewadi, India.
Payne, Arthur Raymond, B.S., M.S.	Hazel Atlas Glass Co., Clarksburg, W. Va., U.S.A.
Richardson, Elwood A.	Glass Technology Dept., National Lamp Works of General Electric Co., 1133, East 152 Street, Cleveland, Ohio, U.S.A.
Ross, F. T.	Wooloware Road, Burraneer Bay, *via* Sutherland, N.S.W., Australia.
Stokes, Lewis L.	The Cumberland Glass Manufacturing Co., Bridgeton, N.J., U.S.A.
Tiebout, Cornelius H., A.M.	Glass Manufacturer, 921, Lincoln Place, Brooklyn, N.Y., U.S.A.
Varshnei, B. D., L.T.C.	Department of Glass Technology, The University, Sheffield, and United Provinces Glass Works, India.
Williams, J. Harvey	Cumberland Glass Manufacturing Co., N.J., U.S.A.

PROCEEDINGS OF THE THIRTIETH MEETING.

HELD in the rooms of the Institute of Chemistry, 30 Russell Square, London, on Wednesday, December 17th, at 2 p.m. Mr. S. N. JENKINSON, President, in the chair.

The following resolutions, of which notice had been given, were put to the meeting and carried, namely:—

(1) That in order to meet the convenience of American members and to facilitate the business of the Society, an American Treasurer be appointed.

(2) That on and after January 1st, 1920, the following shall be the annual subscriptions of American members:—

- (*a*) Collective Members, 15 dollars.
- (*b*) Ordinary Members, 7 dollars.

The PRESIDENT, on behalf of the Council and Members of the Society, then presented a silver bowl to Mr. Frank Wood, C.B.E., first President of the Society, and a silver tea service to Dr. W. E. S. Turner, O.B.E., Secretary of the Society and Editor of the Journal, in recognition of the valuable services they had rendered in connection with the founding and consolidation of the Society. Before making the presentation the PRESIDENT called upon Mr. Connolly, Chairman of the Presentation Committee, to address the meeting.

Grateful acknowledgments of the gifts were made by Mr. Wood and Dr. Turner, as well as by Mrs. Turner.

A vote of thanks was then passed to the Council of the Institute of Chemistry for so kindly providing accommodation for the meeting, and to Mr. R. B. Pilcher, the Registrar and Secretary of the Institute, for the help he had personally rendered.

A paper by Dr. W. E. S. TURNER entitled, "The Glass Industry of North America," embodying the results of his survey of a large number of glassworks personally visited, was distributed among the members present, and taken as read.

Mr. J. CONNOLLY addressed the meeting on the subject of his visit, and explained a number of lantern slides which had been specially prepared for the meeting by Dr. Turner.

Dr. M. W. Travers followed with an account of his own visit to America.

An animated discussion followed, in which there took part Messrs. Frank Wood, F. Cossor, J. Connolly, E. Bateson, G. Simpson, G. Dowse, A. S. Giles, T. C. Moorshead, Dr. Travers, Dr. Turner, and the President.

A special feature of the meeting was the exhibition of a large number of specimens of American glassware, sands, etc., which had been collected by Dr. Turner during his tour in America.

Dr. Travers and Messrs. R. W. Munro, Ltd., London, also exhibited a large dividing machine of new type, and members had an opportunity of seeing it at work.

The following members were elected:—

Ordinary Members.

Bain, Robert Davos, Ph.D.	Works Chemist, Caribonum Co., Ltd., Leyton, London, E. 10.
Graham, James Lindsay	2, Central Buildings, Westminster, London, S.W. Supervising Engineer and Works Manager, British Window Glass Co., Ltd., Queenborough, Kent.
Hailwood, Ernest Arthur	The Towers, Churwell, Leeds. Managing Director, Messrs. Ackroyd & Best, Ltd., Morley, Leeds.
Shively, R. R., Ph.D.	c/o Y.M.C.A., Fairmont, W.Va. Chemist, Monongah Glass Co., Fairmont, W. Va., U.S.A.
Tillotson, Edwin Ward, Jr., B.A., Ph.D.	511, South Lang Avenue, Pittsburgh, Pa., U.S.A. Chemist. Assistant Director, Mellon Institute, University of Pittsburgh, Pa., U.S.A.
Wallis, Percy	Percy Villa, Queenborough, Kent. Student in Department of Glass Technology, University of Sheffield.

PRESENTATIONS TO MR. WOOD AND DR. TURNER.

The early stages of the December meeting were marked by a ceremony of exceptional interest, when the President, on behalf of the Council and Members of the Society, made presentations to W. F. J. Wood, Esq., C.B.E., B.Sc., first President of the Society, and to W. E. S. Turner, Esq., O.B.E., D.Sc., M.Sc., Honorary Secretary of the Society and Editor of the Journal.

The President said that members felt they would like to place on record their appreciation of the services rendered by Mr. Wood and Dr. Turner in connection with the founding and consolidation of the Society.

Mr. Connolly, Chairman of the Presentation Committee,* said that he had never had a task so easy as that of arranging for the presentation. He stated that, in the case of Mr. Wood, a sum of money was to be placed at the disposal of the University of Sheffield, the interest on which was to be devoted to providing an annual prize. This prize would be of the value of about £5, would be awarded in the Department of Glass Technology, and would be known as the "Wood Medal and Prize in Glass Technology."

The President then formally presented to Mr. Wood a handsome silver bowl, inscribed: "Presented to W. F. J. Wood, Esq., C.B.E., by the Society of Glass Technology to mark his services as First President of the Society, 1917—1919."

Mr. Wood, in acknowledging the gift, said that he was quite overwhelmed and was experiencing one of the most embarrassing moments of his life, yet one of the proudest. He referred to the early days of the Society, the first meeting being held on November 9th, 1916, when fifty-one persons were present. The success of the Society was, he thought, due to the Journal, which in his opinion was the finest journal in the world. He very much appreciated the kindness of the members in giving him so handsome a souvenir, the more especially as many of them were his trade competitors. He was sure his wife would admire the bowl.

---

* The Committee consisted of Messrs. J. Connolly, W. J. Rees, and F. Sweeting.

The presentation to Dr. Turner followed, and took the form of a four-piece silver tea service, the inscription being: "Presented to Dr. W. E. S. Turner, O.B.E., by the Society of Glass Technology, December, 1919."

Dr. TURNER, in the course of his reply, spoke feelingly of the kind references that had been made regarding himself and the work he had been able to do. He went on to say that, two days before he sailed for America in August, 1919, he had been the happy recipient of a cheque for £185 from the Presentation Committee, accompanied by a letter from the PRESIDENT and one from Mr. Connolly. [Copies of these letters are appended.] Speaking of the early days of the Society, he remarked that he was told, prior to the inception of the Society, that they would not get 200 members in two years. In point of fact, that number was easily exceeded in the first year. Dr. Turner went on to pay a tribute to his wife, to the officers of the Society, and to his colleagues and assistants in the Department of Glass Technology, without whose co-operation what had been accomplished would not have been possible.

Mrs. Turner also expressed her thanks to the Society for the handsome present which had been so kindly made.

The total amount received by the Presentation Committee for the Testimonial Fund was £391 13*s*. 9*d*.

COPY.

NORTH BRITISH STATION HOTEL,
EDINBURGH.

Aug. 10*th*, 1919.

DEAR TURNER,

It is a great pleasure to me to write you and ask you to accept the enclosed from the members of the Society of Glass Technology. Please accept it as a token of our goodwill, as a small compensation and recognition of all the work that you have done for the Society and for the trade.

I can assure you that we are glad to be able to hand this sum over to you before your holiday, and thus help to make your holiday a real one. Our members, the glass trade, and the country owe you a debt that we can never repay, but our Testimonial will show you that we recognise the debt.

With every good wish for a cheerful holiday.

Yours sincerely,

(Signed) STANLEY JENKINSON.

COPY.

August 11*th*, 1919.

THE LALLIES,
1 MOORFIELD RD.,
PENDLETON, MANCHESTER.

DEAR DR. TURNER,

Our esteemed President, Stanley Jenkinson, Esq., M.B.E., has requested me to hand you the enclosed cheque, value £185, on behalf of the members of the Society of Glass Technology, as a slight token of their esteem and high regard and sincere appreciation of your painstaking, devoted services as Secretary and one of the founders of the Society.

What you have done for the glass industry can never be forgotten by those who have the interest of the industry at heart, and feel that posterity will hold you, as our members do, in loving remembrance for your fidelity.

Your services have indeed been great, and the more one thinks of them the more one realises his indebtedness to you.

We have no doubt that when your cherished desire to visit our American and Canadian Members has been gratified, you will bring to the Society such a harvest as will increase rather than diminish the indebtedness we owe you for your magnificent services so cheerfully given.

The tokens of affection and sincere appreciation accompanying the subscriptions sent to me for your Testimonial Fund are so spontaneous and generous that they will, I am sure, stimulate and encourage you on your holiday and future work.

We sincerely pray that you may realise your fondest expectations and gather that needed strength and vigour, and return home with an added store of vitality that will more than compensate for the time spent.

I sincerely support our President's fondest wishes, and tender you on behalf of the subscribers their loving regards and esteem with best wishes for a most successful trip and safe return to your native land, where loving hearts eagerly await you.

We hope on your return to offer you a further tangible expression of our appreciation—one that shall adorn your home and in which your dear wife may share.

Believe me,

Yours very sincerely,

(Signed) JOSEPH CONNOLLY.

TRANSACTIONS

LIST OF ABBREVIATIONS EMPLOYED IN THE JOURNAL.

Abbreviated Title.	Journal.
Amer. J. Sci.	American Journal of Science.
Analyst	The Analyst.
Ann. Physik	Annalen der Physik.
Ann. Physique	Annales de Physique.
Ber.	Berichte der Deutschen chemischen Gesellschaft.
Ber. Deut. physikal. Ges.	Berichte der Deutschen physikalischen Gesellschaft.
Bull. Soc. d'encouragement pour l'Ind. Nat.	Bulletin de la Société d'encouragement pour l'Industrie Nationale.
Chem. News	Chemical News.
Chem. Zeitung	Chemiker Zeitung.
Compt. rend.	Comptes rendus hebdomadaires des Séances de l'Académie des Sciences.
Deut. Mech. Zeitung	Deutsche Mechaniker-Zeitung.
Elektrotech. Zeitsch.	Elektrotechnische Zeitschrift.
Glashütte	Die Glashütte.
Glasindustrie	Die Glasindustrie.
J. Amer. Cer. Soc.	Journal of the American Ceramic Society.
J. Amer. Chem. Soc.	Journal of the American Chemical Society.
J. Ind. Eng. Chem.	Journal of Industrial and Engineering Chemistry.
J. Physical Chem.	Journal of Physical Chemistry.
J. pr. Chem.	Journal für praktische Chemie.
J. Russ. Phys. Chem. Soc.	Journal of the Physical and Chemical Society of Russia.
J. Soc. Chem. Ind.	Journal of the Society of Chemical Industry.
J. Washington Acad. Sci.	Journal of the Washington Academy of Sciences.
Ker. Rundschau	Keramische Rundschau.
Mon. Scient.	Moniteur Scientifique.
Optician	The Optician and Scientific Instrument Maker.
Phil. Mag.	Philosophical Magazine.
Phil. Trans.	Philosophical Transactions of the Royal Society of London.
Phys. Review	Physical Review.
Physikal. Zeitsch.	Physikalische Zeitschrift.
Proc. Inst. Chem.	Proceedings of the Institute of Chemistry.
Proc. Phys. Soc.	Proceedings of the Physical Society of London.
Proc. Roy. Soc.	Proceedings of the Royal Society.
Sprechsaal	Sprechsaal.
Tonind. Zeit.	Tonindustrie-Zeitung.
Trans. Amer. Cer. Soc.	Transactions of the American Ceramic Society.
Trans. Amer. Illum. Eng. Soc.	Transactions of the American Illuminating Engineers' Society.
Trans. Cer. Soc.	Transactions of the Ceramic Society.
Trans. Farad. Soc.	Transactions of the Faraday Society.
Trans. Optical Soc.	Transactions of the Optical Society.
Zeitsch. analyt. Chem.	Zeitschrift für analytische Chemie.
Zeitsch. angew. Chem.	Zeitschrift für angewandte Chemie.
Zeitsch. anorg. Chem.	Zeitschrift für anorganische Chemie.
Zeitsch. Elektrochem.	Zeitschrift für Elektrochemie.
Zeitsch. Instrumentenkunde	Zeitschrift für Instrumentenkunde.
Zeitsch. physikal. Chem.	Zeitschrift für physikalische Chemie, Stöchiometrie und Verwandtschaftslehre.

S K . . . . Seger Cone.

All temperatures are expressed on the Centigrade scale.

The abstracts of patents are taken by kind permission of the Controller, H.M. Stationery Office.

I.—*Provisional Specifications for Glass Refractories.*

By The Refractories Research and Specifications Committee of the Council.

Section I.

Definitions and Standards.

1. The term "provisional" implies that the specifications are intended to be amended as soon as fuller data on the properties of refractory materials become available. The present specifications are based on the best existing experience of the service which glass refractories should afford. Greater stringency can only be demanded when our knowledge is better defined.

2. The methods of analysis and the tests referred to in these specifications are, unless otherwise specified, those drawn up by the Committee of the Ceramic Society on the Standardisation of Tests for Refractory Materials, and published in the Transactions of the Ceramic Society, 1918, Vol. 17, p. 300.

SECTION II.

The Specifications.

1. TANK BLOCKS.

At the request of the purchaser, the following data shall be supplied for his personal information only, together with average samples true to bulk:—

(*a*) Analysis, which shall show content of silica, alumina, iron oxide, titanium oxide, lime, magnesia, potassium oxide, and sodium oxide.
(*b*) Refractoriness measured by Seger cones.
(*c*) Volume porosity.
(*d*) Linear contraction or expansion after being heated to a temperature equivalent to cone 14.
(*e*) Crushing strength.

Specification.

1. *Refractoriness.*—Cones cut from the blocks shall not be more fusible than cone 30. The test shall be carried out in an oxidising atmosphere, the temperature of the furnace being increased regularly at the rate of 50° per five minutes.

2. *Texture.*—The blocks shall contain no patches of ironstone or other segregated impurity. They shall be uniformly burnt throughout, and if any blue, black, or brown core is present, it shall be of the minimum extent practicable, having regard to the size of the block. The blocks shall be of regular texture and free from holes and flaws. The arrisses shall be as reasonably sharp as is consistent with the size of the grog used. All surfaces shall be sufficiently true and plain as to permit of the blocks being walled together without appreciable joint space on the exposed face.

3. *Porosity.*—The volume porosity, that is,

$$\frac{\text{The volume of pores} \times 100}{\text{Volume of piece (including pores)}},$$

shall not exceed:—

For flux-line blocks	18 per cent.
,, replacement flux-line blocks	23 ,,
,, bottom side blocks	25 ,,
,, tank bottom blocks	30 ,,

4. *After Contraction or after Expansion.*—Test-pieces (about 3 inches in length and 1 to 2 inches in depth and breadth) taken from any portion of the blocks after being heated to and maintained for two hours at a temperature equivalent to cone 14 shall not show when cold more than 2 per cent. linear contraction or expansion. When the test temperature has been reached, the furnace shall be maintained constant throughout the test period.

5. *Crushing Strength.*—The blocks shall be capable of withstanding a crushing strain of not less than 1,600 lb. per square inch. The portion of the block tested shall be a 4-inch cube, and shall have the two ends which come in contact with the jaws of the machine ground or sawn flat and made truly parallel by facing with plaster of Paris in the usual way.

6. *Inspection and Testing.*—The purchaser or his representative shall have access to the works of the maker at any reasonable time, and shall be allowed to inspect the blocks before delivery. Duplicate test-pieces representative of the bulk of the material ordered shall be selected prior to delivery. The cost of the blocks damaged for the purpose of obtaining test-pieces shall be borne (*a*) by the purchaser when the material is proved satisfactory, (*b*) by the maker if unsatisfactory.

2. Silica Bricks and Cement.

At the desire of the purchaser, the following data shall be supplied for his personal information only, with average samples true to bulk:—

(*a*) Analysis.
(*b*) Refractoriness.
(*c*) Linear expansion after being heated to cone 12.

Specification.

1. *Chemical Composition.*—The bricks shall contain not less than 94 per cent. of silica and not more than 2 per cent. of lime.

2. *Refractoriness.*—Test-pieces shall not be more fusible than cone 32 (about 1710°). The test shall be carried out in an oxidising atmosphere, the temperature of the furnace being increased at the rate of about 50° per five minutes.

3. *After-expansion.*—A test-piece after being heated to a temperature equivalent to cone 12 for two hours shall not show, on cooling, more than 0·75 per cent. linear expansion.

4. *Texture.*—The bricks shall be uniformly burnt and shall have a regular texture with no holes or flaws.

5. *Variations from Measurements.*—All surfaces shall be reasonably true, and there shall not be greater variation than ±2 per cent. from any specified dimension.

Silica Cement shall in all cases be finely ground and suitable for binding together the bricks for which it is supplied. It shall contain not less than 92 per cent. of silica, and shall be capable of withstanding the same test for refractoriness as the brick.

3. Raw Clays and Grog.

Specification.

1. *Mixture.*—Clay mixture for pots shall consist of at least three portions:—

(*a*) Bind clay.
(*b*) Base clay.
(*c*) Grog.

At the desire of the buyer, the following data shall be supplied with *samples true to bulk*:—

2. *Chemical Composition.*—The analysis shall show content of SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, K_2O, Na_2O, and the loss on ignition.

3. *Fusion Test*, which shall record:—

(i) Squatting temperature, measured by Seger cones, with equivalents in °C. and °F.
(ii) Squatting temperature under load in °C. and °F. by standard test to be defined.

4. (*a*) *The Bind Clay* shall be a fat, plastic, weathered clay.
(*b*) *The Base Clay* shall be a highly refractory clay. Lumps shall be specially selected and hand-picked free from pyrites.
(*c*) *The Grog* shall be prepared from well-burnt pieces of selected refractory clay. Burnt blocks shall show no sign of blue-stoning or black core. Nothing of the nature of ordinary firebrick shall be used for grog.

5. A sample of any portion when made up and fired to 1400° shall not show decided speckling due to iron in a segregated form.

6. A fracture of each portion, when made up and burnt to 1400°, shall show a dense structure, especially the bind clay. A wide range of vitrification is necessary without signs of over-firing.

7. Clay and grog shall be loaded in clean bags securely tied.

SECTION III.

Recommendations and Suggestions.

It is to be clearly understood that manufacturers of glass refractory materials are free to adopt any method by which the materials which comply with the foregoing specifications may be produced, and the following statements regarding composition and methods of manufacture do not constitute part of the specification.

Nevertheless, the Committee believes that some notes, recommendations, and suggestions in regard to processes of preparation and treatment likely to achieve improvement in refractory materials may not be unwelcome. It is in the hope that fruitful results will attend them that the following notes are appended.

1. TANK BLOCKS.

A. *To Refractories' Manufacturers.*

(*a*) The Committee suggests that the clay aggregate for tank blocks should usually consist of three portions:—

1. Bind clay, which should be a fat, aluminous clay.
2. Base clay, which should be a strong refractory clay.
3. Grog, which should consist of the bind- and base-clays mixed together in the finely ground state, tempered, and burned to cone 14.

(*b*) The following compositions and properties are suggested as indicating suitable clays:—

Bind Clay.	*Composition after Burning*
Free silica	In small proportions only.
Alumina	36 to 40 per cent.
Total alkalis	Less than 2·5 per cent.
Total fluxes	Less than 4·5 per cent.

It should have a low sintering temperature, but should not be more fusible than cone 31.

Base Clay.	*Composition after Burning.*
Alumina	25 to 32 per cent.
Total alkalis	Less than 1·4 per cent.
Total fluxes	Less than 4·0 per cent.

It should not be more fusible than cone 31.

(*c*) The following notes are suggestions as to suitable mixtures and methods for the consideration of tank block manufacturers:—

(i) *Tank Bottoms.*

Fat, plastic clay, 1 volume.
Lean or strong clay, 3 volumes.

These clays should be well mixed in the dry, ground condition.

Grog should be made by tempering a portion of the above mixture, making it into slabs (say, 12 inches × 12 inches × 4 inches), and burning to cone 10. The fired slabs should be crushed in a type of crushing machine producing sharp-edged grains with a minimum of fine material.

Mixture for Blocks.

Dry, ground clay of above mixture, 5 volumes.
Grog passing ¼-inch mesh and held by ⅛-inch mesh, 1 volume.
Grog passing ⅛-inch mesh and held by 1/16-inch mesh, 1 volume.
Grog passing 1/16-inch mesh and held by 1/32-inch mesh, 1 volume.

These constituents should be well mixed dry, tempered by the addition of the minimum quantity of water, pugged well or treated in a pan mill with the rolls raised, and then allowed to mature for one month at least.

Blocks should be slowly dried and burned to cone 10.

(ii) *Bottom Side Blocks.*

Fat plastic clay, 2 volumes.
Lean or strong clay, 2 volumes.

Grog should be made from above mixture (as for Bottom Blocks) and burned to cone 12.

Mixture for Blocks.

Dry ground clay of the above mixture, 5 volumes.
Grog passing ⅙-inch mesh and held by ⅛-inch mesh, 1 volume.
Grog passing ⅛-inch mesh and held by 1/16-inch mesh, 2 volumes.
Grog passing 1/16-inch mesh and held by 1/32-inch mesh, 1 volume.

Blocks should be burned to cone 12.

(iii) *Top Side (Flux-line) Blocks.*

Fat plastic clay, 2 volumes.
Strong clay, 1 volume.

Grog should be made by burning the above mixture to cone 14

Mixture for Blocks.

Dry ground clay of above mixture, 5 volumes.
Grog passing $\frac{1}{8}$-inch mesh and held by 1/10-inch mesh, 1 volume.
Grog passing 1/10-inch mesh and held by 1/32-inch mesh, 2 volumes.

Blocks should be burned to cone 14.

(iv) *Replacement (Flux-line) Blocks.*

Fat plastic clay, 1 volume.
*Lower grade fat clay, 1 volume.
Strong clay, 1 volume.

Grog should be made by burning the above mixture to cones 6—8.

Mixture for Blocks.

Dry ground clay of above mixture, 5 volumes.
Grog passing $\frac{1}{6}$-inch mesh and held by $\frac{1}{8}$-inch mesh, 2 volumes.
Grog passing $\frac{1}{8}$-inch mesh and held by 1/16-inch mesh, 2 volumes.
Grog passing 1/16-inch mesh and held by 1/32-inch mesh, 1 volume.

Blocks should be burned to cones 6—8.

B. *To Manufacturers and Users.*

(*a*) Some defects, in particular, blue, black, or brown coring, and surfaces which are not plain, are not easy to avoid in large blocks. The Committee therefore recommends the use of tank blocks with no face having an area greater than 4 square feet.

* *A suitable Lower Grade Plastic Clay* should contain when fired:—
Alumina, 34—38 per cent.
Alkalis, not above 3—5 per cent.
Total fluxes, not above 6·5 per cent.

It should have a low sintering temperature and should not be more fusible than cone 26.

(*b*) The Committee recommends the careful storage of blocks in a dry, warm room, with the blocks raised from the floor.

C. *To Glass Manufacturers.*

The Committee recommends that tank furnaces containing new blocks should be raised to the maximum working temperature and maintained there for at least twelve hours before any molten glass or batch is allowed to come into contact with the blocks.

2. Raw Clays and Grog for Pots.

A. *To Suppliers of Refractory Materials.*

The Committee urges that all care and supervision shall be exercised to see that the clays used are not contaminated with dirt or other foreign matter. Pans and mills should be thoroughly cleansed before use; where sieve bottoms are used, the pans should be swept out every day.

B. *To Pot Makers and Glass Manufacturers.*

The Committee believes that sufficient information exists to enable clays suitable for pots to be classified in three grades according to their composition and fusion temperature. The lowest, or Grade 3, corresponds with the material in general use; Grades 2 and 1 are purer and more refractory.

The following are limits for the composition and fusion temperature suggested in each grade. In each case the compositions quoted are for fired samples.

Grade 1.

BIND CLAY.

Chemical Analysis.—	SiO_2,	60 and under.
	Al_2O_3,	34 and over.
	Fe_2O_3,	1·8 and under.
	Na_2O and K_2O,	1·8 and under.
	MgO and CaO,	1 and under.

Fusion Test.

Squatting temperature, cone 32.

Mechanical Division.

Clay which can be blunged and sieved to pass 80 mesh with not more than 10 per cent. residue.

BASE CLAY.

Chemical Analysis.—

SiO_2,	55 and under.
Al_2O_3,	40 and over.
Fe_2O_3,	1 and under.
Na_2O and K_2O,	1·5 and under.
MgO and CaO,	0·5 and under.

Fusion Test.

Squatting temperature, cone 35.

Mechanical Division.

Ground to pass 80 mesh.

GROG.

Chemical Analysis.—

SiO_2,	50 and under.
Al_2O_3,	40 and over.
Fe_2O_3,	1 and under.
Na_2O and K_2O,	1·5 and under.
MgO and CaO,	0·5 and under.

Fusion Test.

Squatting temperature, cone 35.

Mechanical Division.

Ground to pass 12 mesh.

Temperature of Firing.

Not lower than cone 14.

GRADE 2.

BIND CLAY.

Chemical Analysis.—

SiO_2,	65 and under.
Al_2O_3,	30 and over.
Fe_2O_3,	2 and under.
Na_2O and K_2O,	2 and under.
MgO and CaO,	1 and under.

Fusion Test.

Squatting temperature, cone 30.

Mechanical Division.

Clay which can be blunged and sieved to pass through 50 mesh with less than 10 per cent. residue.

BASE CLAY.

Chemical Analysis.—

SiO_2,	60 and under.
Al_2O_3,	35 and over.
Fe_2O_3,	2 and under.
Na_2O and K_2O,	1·8 and under.
MgO and CaO	0·6 and under.

Fusion Test.

Squatting temperature, cone 32.

Mechanical Division.

Ground to pass 50 mesh.

GROG.

Chemical Analysis.—

SiO_2,	60 and under.
Al_2O_3,	35 and over.
Fe_2O_3,	2 and under.
Na_2O and K_2O,	1·8 and under.
MgO and CaO,	0·6 and under.

Fusion Test.

Squatting temperature, cone 32.

Temperature of Firing.

Not lower than cone 12.

GRADE 3.

BIND CLAY.

Chemical Analysis.—

SiO_2,	70 and under.
Al_2O_3,	25 and over.
Fe_2O_3,	2·5 and under.
Na_2O and K_2O,	2·5 and under.
MgO and CaO,	1 and under.

Fusion Test.

Squatting temperature, cone 28—29.

Mechanical Division.

Ground to 12 mesh.

BASE CLAY.

Chemical Analysis.—

SiO_2,	70 and under.
Al_2O_3,	25 and over.
Fe_2O_3,	2 and under.
Na_2O and K_2O,	1·8 and under.
MgO and CaO,	1·0 and under.

Fusion Test.

Squatting temperature, cone 30—31.

Mechanical Division.

Ground to 12 mesh.

GROG.

Chemical Analysis.—	SiO_2,	70 and under.
	Al_2O_3,	25 and over.
	Fe_2O_3,	2 and under.
	Na_2O and K_2O,	1·8 and under.
	MgO and CaO,	1·0 and under.

Fusion Test.

Squatting temperature, cone 31

Mechanical Division.

Ground to pass 12 mesh.

Temperature of Firing.

Not lower than cone 9.

II.—*Manufacturing Costs in the Glass Industry.*

By J. Dearden Mills.

(*Read at the Manchester Meeting, January* 15*th*, 1919.)

It has been my special privilege as an Accounting Officer of the Glassware Department of the Ministry of Munitions to come into contact with the various types of manufacture that go to make up what is termed the Glass Industry.

To be perfectly frank, when I attempted to introduce my experience of costing in order to obtain results in a glass factory, I was confronted with problems which at first sight appeared to me to be absolutely without solution, and it is only by the unstinted assistance that I have received from the managing and technical staffs of the various factories that I gradually obtained a clear view of most of these solutions, and I am convinced that it is up to the accountant and the technical expert to put their heads together before any progress can be made in obtaining a suitable costing system for a glass factory. The necessity for this will be more apparent when I come to the details of the system.

I have read many books on the subject of "costing," but up to the present have not discovered one that would enable a manufacturer of glass, or his accountant, to ascertain the manufacturing costs of, let us say, a miner's lamp glass or any one of the many thousands of articles that are being turned out by the glass industry to-day. If there is such a book it has not been read by the people it should most concern, because I am sorry to say that costing systems in the majority of factories are conspicuous by their absence. This, I am certain, is not due to the lack of enthusiasm on the part of the manufacturer, but generally to the shortage of staff during the War, and also to want of information concerning useful and simple systems.

Conscious of the vital necessity of costing to the trade, the Glassware Department of the Ministry of Munitions approached the manufacturers with a view to ascertain if they had any objections to accountants visiting their works in order to investigate the position the trade was in from a costing point of view, and I must say that, without exception, the suggestion was met with the best of receptions from all quarters of the industry.

The investigations have been carried out in all sorts and sizes of factories, ranging from the garret lamp worker to the well-equipped and up-to-date establishment. Up to the present, it has not been possible to visit every firm, but even that is not without the bounds of possibility. It is necessary, not only from the individual aspect, but, what is just as important, the national interests, that this great industry shall not be allowed to slide back into the position it was in before the War. We have all been in agreement upon this for a long time, but if the facts are analysed they indicate two prime necessities; we must concentrate on:

(1) Methods of manufacture.
(2) Cost of manufacture.

Of the two, the second is in my opinion the more important, because while ascertaining the cost of manufacture, the flaws in methods come to light; this being so, all will agree that every manufacturer should have a costing system.

The Uses of a Costing System.

Now what use can one make of a costing system?

In reply, I would mention the following:

(1) To regulate selling prices according to cost of manufacture.
(2) To frame estimates and tenders.
(3) To locate non-paying lines or non-paying departments.
(4) To establish a standard of cost for stock purposes.
(5) To detect waste and inefficiency.
(6) To keep each element of cost under observation.

There are a score of other advantages to be gained by the presence of a system in a factory, but they do not become apparent until it is in working order. The secret of the success of a system is to ensure that ordinary book-keeping methods are planned to assist with the costs, and the idea that the introduction of a costing system means a huge increase of clerical staff is entirely erroneous. I go so far as to say that in a number of cases it will be discovered that much time has been wasted in keeping unnecessary accounts, analysing invoices into meticulous detail that proves to be useless from a costing point of view, and certainly worthless from an accounting aspect, because the human element creeps in and the books cannot be made to balance.

I cannot emphasise too much at this stage the necessity of keeping accurate records of all business transactions in such a manner that will enable an accountant to give a true statement of affairs from time to time.

This necessity for accurate records may perhaps be taken for granted; but I assure my readers that from personal experience there is great need for improvement in this direction throughout the industry.

The Elements of Cost.

The elements of cost may be summarised in the following way (Table I.).

TABLE I.

1.			2.	
Direct charges or Prime Cost.			Indirect charges or Oncost.	
(*a*)	(*b*)	(*c*)	(*a*)	(*b*)
Direct wages.	Direct material.	Chargeable expenses.	Indirect works expenses.	Indirect general expenses.

The total of (1) and (2) gives us the gross cost of production.

Since oncost represents indirect charges, it must necessarily be applied by estimation based on past experience, or, in the case of a new undertaking, upon the experience of others modified to one's own plans. The estimate should be based upon the relationship of indirect charges to some direct charge. I advocate the theory that direct or productive wages form the most steady element upon which to apply oncost.

At intervals, profit and loss and trading accounts should be prepared from the general books to provide a means of verifying or correcting the existing oncost rates.

Cost of Glass Making.

It is of the utmost importance that the cost of making the glass should be ascertained quite separately from the labour cost of blowing or any subsequent operations that may be necessary to complete the article, and with this in view the elements of cost of making the glass may be tabulated in the following way:

(1) Batch (including carriage).
(2) Mixing cost.
(3) Furnace charges.

Let us consider the first of these elements, namely, the Batch. Its cost is determined by taking the various chemicals and pricing them at current rates. In some instances it may be desirable to work upon the total quantity of new batch consumed in a given period, whilst in other cases it will be more convenient to base the calculation upon the cost per lb.

Next we come to Mixing Cost. This should include:

Wages of mixers; cost of sand burning; crushing, grinding, and storing in bins; repairs and renewals to machinery and mixing plant; motive power; lubrication, etc.

It would, of course, be applied on the same basis as batch, and new batch only should stand the cost of mixing, as cullett is not subject to a further mixing.

Combining the two factors, namely, batch, and the cost of mixing it, we arrive at the Cost of Mixed Batch. This is subject to further adjustment before we are able to arrive at the cost of batch converted into melted glass. I will give you an illustration to make this point clear.

Assuming that mixed batch weighing 1 lb. costs 2·694*d.*:

Shrinkage of weight by moisture in the purchased sand, lead, etc., and wastage in transit, reduces the weight by 10 per cent.		0·1
Dry batch ready for fusion... ...	=	0·9 lb. costs 2·694*d.*
Loss in fusion, by evolution of gases, etc., further reduces the weight by 10 per cent.		0·09
Melted glass in pot or tank ...	=	0·81 lb. costs 2·694*d.*
Loss by volatilisation, proofs, and skimming again reduces the weight by 10 per cent.		0·081
Therefore, batch in workable glass	=	0·729 lb. costs 2·694*d.*

Therefore the batch in 1 lb. of workable glass costs 3·695*d.*

The percentages I have used in this illustration are fictitious, and the decision of such factors in actual factory practice would necessarily be made by the technical staff of the firm as a result of experience. The percentage would, of course, vary according to the composition of the batch, and would be higher in the case of new batch than in batch helped by cullett.

Furnace Charges.

Now we have to consider the Furnace Charges. Where more than one furnace is installed, it is advantageous to keep the cost of working each furnace separately, as one furnace would probably be more expensive to work than another.

The total cost of working, including lehrs, glory holes, pot arches, and smithy, could be regarded as part of furnace charges, but it will be found advantageous to separate them, if possible, as it is incorrect to saddle articles with such cost if they did not call for lehr or glory hole treatment; neither would it be correct to make all articles bear the cost of re-annealing where a separate re-annealing lehr is working.

I will give you a suitable allocation that could be made by analysing furnace charges under the following headings:

Total ...	*No. 1 Furnace.*	*No. 2 Furnace.*	*Main Lehr.*	*Re-annealing Lehr.*	*Glory Holes.*	*Pot Arches.*	*Smithy.*

The various items to be regarded as Furnace Charges are:

(1) Wages of engineers, bricklayers, labourers, claymen, lehr attendants, smithy men, and stokers.

(2) Cartage charge for removal of clinkers.

(3) Fuel consumed, including carriage.

(4) Pots (or clay where pots are made on the premises), including carriage.

(5) Firebricks, fireclay, bricks, tiles, etc., including carriage.

(6) Clay rings and pot sundries.

(7) Repairs and renewals to fire irons, fire bars, blowing irons, etc.

(8) Repairs and renewals to furnace (or tank).

(9) New moulds and repairs thereto.

(10) Oil, carbon, and other sundries for glasshouse use.

Should a departmental system of costs be used, it would also be possible to absorb in furnace charges such items as rent, rates and taxes, depreciation, etc., applicable thereto, and thus reduce the expense that has in a general way to be charged as an oncost where a departmental system is not in existence.

Having determined the furnace charges in total, it is quite a simple matter to convert them into a unit, such as the cost per week, per tank, per pot, or per pot arch; and it will be appreciated that by dividing the cost per unit by the corresponding output of such unit, we determine the furnace charges to be borne by the output.

Assuming that the output is expressed in lbs., as in the case of gauge glass tubing, the resulting figure is the cost of furnace charges per lb., and as we have already determined the cost per lb. of batch in workable glass, the total of these two items produces the cost of workable glass per lb.

If operations subsequent to blowing are performed, the cost of glass per lb. in the finished articles can be determined by the following table:

TABLE III*a*.

$$\text{(Cost of mixed batch in terms of workable glass per lb.)} = \frac{\text{Furnace charges per unit.}}{\text{(Output per unit in lb.)} \times \text{Percentage reaching store after all operations.}}$$

Where varied articles are produced from a pot or other unit and it is impossible to arrive at the output of such a unit, it will be necessary to theorise the output on the lines of the following table:

TABLE III*b*.

$$\text{(Cost of mixed batch in workable glass per lb.)} = \frac{\text{Furnace charges per unit.}}{\underset{(a)}{\text{Quantity of batch put into pot or tank in lb.}} \times \underset{(b)}{\text{Percentage of weight surviving fusion.}} \times \underset{(c)}{\text{Percentage worked from pot or tank.}} \times \underset{(d)}{\dfrac{\textit{Glass in goods}}{\text{glass gathered.}}} \times \underset{(e)}{\text{Percentage or blown goods reaching store.}}}$$

(*a*) The total weight of batch should be readily obtained.

(*b*) Weight lost in fusion is dealt with under batch.

(*c*) The percentage worked from a unit could be calculated with the assistance of the technical expert or from practical experience.

(*d*) The ratio of glass in goods to glass gathered can be established on the following lines:

(1) Weight of finished article	2·5 oz.	25 per cent.
(2) Portion cut or worked off	5·4 oz.	
(3) Weight off blowing iron	7·9 oz.	
(4) Weight left on blowing iron	2·1 oz.	
Weight gathered	10·0 oz.	100 per cent.

The factors are all ascertainable from practical experiments.

(*e*) The percentage reaching the store can be determined in the following manner:

Article.	No. blown.	No. surviving the lehr.	Loss between operations.	Percentage reaching the store.
—	100	90	(12·5 × 90) = 11·25 per cent.	78·75

It will be noticed that the cullett factor is covered by our second formula, as the furnace charges are borne by the surviving quantity of finished articles, the resulting cullett again bearing furnace charges when next used, and having the original mixed batch value.

The use of cullett has the effect of reducing the furnace charges per unit by allowing more units to be worked in a given period than if entirely new batch was used.

At this stage we have arrived at the cost of making glass, including a provision for loss subsequent to gathering, so as to determine the cost of glass in the finished goods, quite apart from productive labour or oncost.

Labour Charges.

Let us now deal with the subject of Labour Charges.

Labour is either productive or unproductive. In the case of unproductive labour, this should be charged to the indirect expense account of the department in which it is incurred, to be treated as oncost against this department. A shop foreman's time should be handled in this manner, or at least that portion of it which is entirely unproductive. Necessary idle time through intermittent work or stoppage of machinery, etc., should be similarly treated.

Piecework eliminates unproductive labour as far as operators are concerned, and when timework on hourly or weekly rates is in force, the time should be recorded on time sheets or books, so that it can be properly analysed in the main wages book. These time sheets should be designed not only to account for the time of an employee, but also to record the articles commenced and the number completed, this resulting quantity to bear the labour cost of the total commenced. It will also furnish the percentage of loss between the operations, which is an important factor in assessing the cost of glass in finished articles, in addition to figuring the breakage, loss of labour between operations, an illustration of which you will find in Table IV.

TABLE IV.

Breakage, Loss of Labour between Operations.

Operation.	Labour cost of operation. *d.*	Cumulative labour cost. *d.*	Loss per cent.	Loss in pence.
Blowing	30·66	30·66	—	—
Cutting off	1·64	32·30	2·96	1·01
Grinding............	10·56	42·86	3·85	1·24
Washing	1·26	44·12	0·87	0·37
Examining	0·88	45·00	4·59	2·03
Papering............	0·28	45·28	0·23	0·10
		Total	12·50	4·75

The figures used in this table are simply for the purpose of illustration.

The breakage loss of labour between operations is determined by figuring the percentage loss at any stage upon the accumulated labour cost up to the previous stage, as the cost of any one operation is absorbed by the surviving quantity throughout. The breakage loss of departmental oncost can be figured in a similar fashion, or Table IV could be utilised to supply this information by subdivision.

Oncosts or Overhead Charges.

An attempt should be made to absorb as much indirect expense as possible in the expense account of the department concerned, thus reducing the amount of oncost to be applied generally over the whole of the firm's operations. It is obviously unfair to saddle work produced by hand only with expense peculiar to machine production, and one class of goods may be manufactured with much less supervision than another type.

Rent, rates, and taxes may be readily allocated on the basis of floor space occupied, and depreciation could be easily charged against the plant concerned.

Such charges that cannot be allocated to particular departments have to be dealt with as a general oncost percentage to be assessed on the productive labour involved in the manufacture of the article under consideration.

With these facts we can prepare a summary of costs on the lines of Table V.

TABLE V.

	Material. Pence	Productive labour. Pence.	Departmental oncosts. Pence.
A. Cost of glass, including batch, furnace charges, lehrs, glory holes, pot arches, smithy work per formula : 8 lb. @ 10d. per lb.	80·00	—	—
B. Blowing (labour)	—	20·00	10·00 (50%)
C. Cutting-off (labour).........	—	7·00	0·70 (10%)
D. Grinding (labour)	—	10·00	1·00 (10%)
E. Washing (labour)	—	2·00	0·10 (5%)
F. Inspection (labour).........	—	5·00	0·50 (10%)
G. Papering (labour)	—	0·50	0·05 (10%)
H. Breakage, loss of labour, and departmental oncosts, between operations, per Table IV. ...	—	4·75	0·475 (10%)
	80·00	49·25	12·825

Works cost.
Add :—General oncost of 25 per cent. on productive labour .... 142·075
12·3125

Gross cost. .... 154·3875
Add :—20 per cent. profit .... 30·8775

Selling price .... 185·2650

This summary enables us to arrive at the selling price by adding to the gross cost a percentage to produce the necessary profit. The question of profit is one entirely for the decision of the management.

I have outlined as clearly as possible the various factors of this costing system. There may be certain sections that experience would improve, and I should greatly value any suggestions that manufacturers can make with this object.

In conjunction with this paper, I am drawing up a system of accounting that can be applied to most glass factories, with such variations and amendments as might be found necessary. If there is anyone interested in this phase of the subject I shall be pleased to forward a copy of the suggested system to them when completed if they will communicate with me.

MINISTRY OF MUNITIONS,
GLASSWARE DEPARTMENT,
117, PICCADILLY, W.1.

Discussion.

Mr. **Duncan Webb**: Mr. Mills had presented to the Society a very good, if elaborate, system of costing, and he (Mr. Webb) would like to express his thanks. At the same time, he would point out that the cost of goods had sometimes to be priced in front of the customer, and the price was affected by the market rates.

Mr. J. **Connolly**: A system and method of costing such as discussed by Mr. Mills is the first principle in all successful undertakings, in order to ensure what keen business men desire, namely, to secure profitable, paying patrons.

Manufacturers and inventors are now chiefly concerned as to what methods to adopt to increase their productive capacity, to reduce cost of production, and at the same time pay higher wages to labour. Such ambitions ought to open a wide field of investigation and stimulate manufacturers to scrutinise every operation. Thus, the employment of a works chemist who thoroughly understands the behaviour of the ingredients of the batch that goes to make glass ought to be regarded as essential. A chemist would save more than his salary and add to the reputation of the firm for higher grade ware, as well as detecting adulteration of the chemicals supplied. It is an indisputable fact that chemicals are supplied that are often not up to the standard requirements; consequently, inferior ware is produced, which has to be sold at low-grade prices.

The glass bottle industry of this country has by its adoption of the Siemens principle of continuous gas tanks, along with the modern gas-fired lehr, more than justified the scrapping of stage-coach methods by the increase in production and lower working costs. The continuous gas-fired tank in turn made it possible for the bottle manufacturers to adopt bottle-making machinery, for which the industry owes a debt of gratitude to our countryman, Mr. Ashley, of Castleford, Yorkshire, who invented the first successful bottle machine more than thirty years ago, using a principle which all successive inventors have applied.

There is every justification for prophesying that a still further revolution is about to be realised by the adoption of the flowing device in place of hand gathering, which is very trying to the workmen during hot weather. The war has brought its problems to the flint glass trade as to what method and organisation to adopt to meet foreign competition, and also to produce what had hitherto been supplied from abroad. We ought in this country to develop this side of the industry, and so provide work and good wages for a vast number of our rising generation, many of whom slide into blind-alley employment. If this end is to be realised, it cannot be accomplished on the phrase "business as usual" coined in the days of 1914.

Our united efforts must be to design every labour-saving device possible. Here I would remark that labour-saving devices are not a means of creating unemployment. They create employment, bring higher wages, and at the same time lower the cost of production. When bicycles were expensive, the supply was small, but when the cost fell to half the price through using labour-saving machinery, the production became tenfold; consequently, employment was increased and added pleasure was given to life in the increased number of users. The same is true of motor-cars.

Our members had an opportunity this morning on their visit to Ford's Motor Factory of seeing what system and organisation can accomplish. They had a demonstration that by up-to-date machinery, organisation, and standardisation, a very cheap car could be made, workmen could be paid higher wages than the standard rate, whilst the production of motor-cars built was enormous. Their surprise was great when they saw a Ford car erected and run round the works yard in seven minutes.

Coming now to systems of accounting, I hold that the method of costing per pound method is very inaccurate, as a light-weight article when finished may cost more and be of greater value than one which is heavier, solely on account of its weight. A longer time is required to empty a pot or tank where small ware is produced, whilst the cost for fuel and labour may be much greater. In checking the output of different furnaces, it is well also to record systematically the inside dimensions of the pot, the area of the ports, and the cubical contents of the generators, as these affect the melting capacity.

The following system, which I adopted in our works, has proved trustworthy, both for costing and in proving that increased production means lowering the cost and paying higher wages.

Let us assume that a balance-sheet shows the whole of the standard charges for the year at £10,000, except for glass workers, cost of metal, and wages of takers-in and machine boys. Then of every conceivable expense incurred nothing can escape, even a pen nib, or depreciation made at the stock-taking.

If the total expenses for the year are £10,000, and if from the records the loss of working time, for various causes, is equivalent to two weeks' stoppage, then the average weekly charge will be

£10,000 divided by 50, or £200 per week. If the stoppages exceed two weeks, divide by the actual number of working weeks.

If there are five chairs or machines working night and day shifts, equivalent to ten chairs, the standing charge is £20 per chair or machine; if six chairs or machines, we have a reduced standing charge of £16 13*s.* 4*d.* per chair or machine. There is, therefore, a substantial lowering of costs by having the furnace working fully staffed.

We then have, in each case for five chairs, but with different outputs:—

(a)

	£	*s.*	*d.*
Cost per hole	20	0	0
Wages, 60 gross bottles 2*s.* 6*d.* per gross	7	10	0
Metal, 2*s.* 6*d.* per gross	7	10	0
Two boys	2	0	0
	37	0	0

Or, cost per gross is 12*s.* 4*d.* at the works.

(b)

	£	*s.*	*d.*
Cost per hole	20	0	0
Wages, 70 gross bottles 2*s.* 6*d.* per gross	8	15	0
Metal 2*s.* 6*d.* per gross	8	15	0
Two boys	2	0	0
	39	10	0

Or, cost per gross, 11*s.* 7*d.*

The above demonstrates that by the production of 10 gross more per week, a reduction equal to 9*d.* per gross is brought about.

Assuming six chairs at a standing charge of £16 13*s.* 4*d.* instead of five chairs at £20, then 60 gross, instead of costing 12*s.* 4*d.* per gross, would only cost 11*s.* 3*d.*, and with 70 gross production only 10*s.* 7½*d.* instead of 11*s.* 7*d.*

It may be objected that to adopt the previous year's balance-sheet is not a true guide for the current year; but the objection is met by adding any advance in materials or wages during the year to the cost per working hole or chair, or, if wages rise or fall, corresponding alteration is made.

Finally, I desire to say that changes in methods of production or alteration in plant should be the subject of discussion and research, not arbitrarily enforced, so that confidence in the decisions of the Glass Trade Parliament would be engendered. The primary need is a new spirit and a wider outlook that will give employer and workman a new driving force in the coming days.

Mr. F. Edward said that he could not understand Mr. Mills's difficulty in allocating time charges. He would point out that in other industries men work to a time card, which is entered up in the office.

Mr. Duncan Webb said that in the flint glass trade it was difficult to work on a system of costs per lb. of glass owing to the great variety of articles made. Some men would make 50 lb. weight, whereas others might make 1,000 lb. weight of articles.

His own system was to consider the total number of turns per year, divide this number into all fixed charges, make allowance for volatilisation and losses from the glass, and so get the charges per turn. He regarded each chair as carrying the same charges and rent for the time it was occupied. In his own branch of the industry, there were further charges to consider beyond the cost of making the article, since etchers, cutters, and engravers all added their quota to it.

Mr. S. N. JENKINSON stated that he had seen in use in 1916 in a Swedish works a system which enabled the profit on the working to be determined at the end of each month.

Mr. JULIAN A. OSLER said that while agreeing with Mr. Jenkinson as to the desirability of including as much as possible as direct wages, he thought it was difficult to do so as regards such items as washing, examining, and papering where a general or mixed trade was being carried on. Where the trade was not of a repetition character, it would be necessary to include these items among oncosts. He agreed that oncosts (as distinct from furnace charges) should be calculated, not as a percentage on labour, but as a percentage on the theoretical wages of the full "chair" employed rather than on the actual wages paid. Having originally added oncosts to actual wages paid, he had produced a total cost of 10·9*d.* on a certain article in the case of a broken chair, as against 11·5*d.* in the case of a complete chair. The complete chair had, however, produced £9 10*s.* higher value in the week, the only saving on the broken chair being £3 wages and 16*s.* cullett. It was obviously fallacious to consider that the broken chair had been more profitable, and by adding the same oncost to each chair a truer result was obtained.

The glass trade was subject to more mishaps and contingencies than most trades, and results would vary greatly from year to year according to one's luck with furnaces. Somewhere in any cost system one had to insure against such contingencies.

III.—*A Costing System for a Glass Bottle Factory.*

By F. Sweeting.

(*A Contribution to the Discussion at the Manchester Meeting, January* 15*th*, 1919.)

Having listened with great interest to the paper read by Mr Mills, I should like to explain a method of costing for glass bottle production which I adopted a few years ago after giving a great deal of consideration to the subject and testing various methods suggested. I rejected the weight unit, as a single unit, as not being trustworthy, and one which if employed wholly would be bound to lead to disastrous results if a change in the proportion of the various descriptions of bottles manufactured should be made.

The Cost of the Raw Materials.

Any system of costing must be capable of being tested and proved by the results of the trading and profit and loss accounts of the firm. First of all, there should be a column in the ledger for the weights of the raw materials and fuel purchased, in addition to the money columns, or these figures should be accurately entered from all invoices into a special book used for this purpose.

For example, in the case of sand, the statement for a period of six months might be:—

Jan. 1st		Tons.	£			Tons.	£
	To Stock ...	200	200	June 30th	By Stocks	300	30
	Purchases ...	600	600	,,	Trading a/c		
Feb.	,,	400	400		Amt. used	3,000	3,000
March	,,	500	500				
April	,,	650	650				
May	,,	500	500				
June	,,	450	450				
		3,300	3,300			3,300	3,300

An account should be kept in the same way for each class of material used, so that at the end of the accounting period the figures would be as follows:—

Column	1 Tons.	2 Cost £	3 Average cost per ton.	4 Percentage of batch.	5 Cost per ton of batch.
Sand	3,000	3,000	20/–	57·70	11/6½
Sulphate of soda	600	2,100	70/–	11·54	8/1
Alkali	400	2,000	100/–	7·69	7/8¼
Limestone ...	1,200	1,200	20/–	23·07	4/7¼
	5,200	8,300		100·00	31/11

Column	6	7	8	9
	Percentage approx. yield say	Total yield tons.	Percentage of glass yield.	Approx. cost of batch per ton of glass produced.
Sand	93	2,700		
Sulphate of soda	41	246		
Alkali	57	228		
Limestone ...	54	648		
		3,822	73·5	£2 3 5

I have only considered for purposes of illustration four common batch materials, but particulars of lead, manganese, oxide of cobalt, fluorspar, burnt lime, clay, potash, and any other materials could be treated in the same way. Having obtained the figures for the first two columns, the average price of the material per ton could be determined and entered in the third column. In charging the materials to the various accounts, the amount paid for carriage on that material should be charged to the same account, so that the cost would be that of the material delivered at the works, the rail account for carriage being dissected and inwards carriage charged to the various accounts for material would leave the carriage account debited with the carriage on outward goods only.

The Cost of the Batch.

Then I find that the easiest and most trustworthy way of obtaining the cost of the batch is to work out the percentage of the various materials used. Considering the figures in column 1 as representing the batch mixing, we obtain the figures given in column 4. It is then very easy to calculate the cost per ton of batch as given in column 5; but we know that a ton of batch does not yield a ton of glass; that sand, especially at certain periods of the year, contains a lot of moisture, and that only a certain amount of other materials enters into the composition of the glass, portions being given off in the shape of gases, which pass away by the chimney stack. It is essential, therefore, to get the average percentage yield of each of the materials used. I have found the figures used in column 6 give very close results. Column 7, then, states the yield in the glass of the materials shown in column 1. Column 8 gives the percentage of this yield, and column 9 the cost per ton of glass on the batch used. These figures should be tested so as to discover any error in the calculations. We have 5200 tons of batch at 31/11—£8298 6*s*. 4*d*. 3822 tons of glass at £2 3*s*. 5*d*.—£8296 18*s*. 6*d*., the percentage of error being negligible.

It will be seen, therefore, that having the composition of the batch and the average yield, the cost of batch per ton of glass can be obtained at any time by taking the current cost of the materials used.

The Cost of Glass Production.

The next item to consider is the charges to be put on the glass per ton. This is a point that may raise the most discussion, but I submit that it can be laid down as perfectly sound policy that the following charges should be put upon the weight of good saleable articles produced:—

	Tons.	Total cost. £	s.	d.
Batch as given above	5,200	8,300	0	0
Wages batch mixers		382	0	0
Fuel used (at 25/– ton)	9,000	11,250	0	0
Wages, founders, teasers, tenters, removers of cave ash, etc., boiler firers making steam for producers, etc.		4,395	0	0
Cost of repairs to furnaces, pots, buildings, including bricklayers' wages, etc. ...		3,822	0	0
		£28,149	0	0

These figures should include the cost of all materials and wages paid to men in any capacity engaged in the production of the glass, so that the total cost of the glass ready in the tank or pot to the point at which it is prepared for the gatherer to gather the metal on to his blowpipe is determined. Taking the yield as given in column 7, we get the cost of glass as £7 7*s.* 3½*d.* per ton, and I do not advocate the weight unit being used at all beyond this point. If one quality and colour of glass only are being made, the above figures would apply to all the bottles manufactured, but as in most cases different colours are being worked, the figures would have to be dissected accordingly.

Bottle Making Costs and Indirect Charges.

After considering the matter very fully from both a theoretical and practical point of view, I have arrived at the conclusion that, at any rate so far as the production of glass bottles is concerned, all the other charges than those shown above must be calculated on the journeys of bottles actually made. This eliminates any error in making allowance for the periods the furnaces are not working on account of repairs, etc. It ensures that the fixed and indirect charges are proportional to the individual cost of the bottle on the time taken by the skilled workman in the production.

Let us assume that during the period of six months 7500 journeys were worked. The charges not affected by the weight of glass produced per set of hands are as follows:—

Cost of moulds, iron and steel used, fitters' wages.
Blow pipes, blacksmiths' wages.
Power and electric light.
Warehouse expenses, straw, packages, sorters and packers' wages.
Depreciation.
Stable expenses.
Rates, gas and water.
Insurance.
Salaries.
Travelling expenses.
Office expenses.
Charges.
Directors' fees.

Total say £15,000 or £2 per journey of bottles made.

	£
Bottle makers' wages	30,000
Special charges not applicable to all bottles produced such as washing, fitting, stopper grinding, fittings for bottles, wages paid for these various operations	3,000

The summarised costs would therefore be:

Glass	28,149
Indirect charges	15,000
Bottle makers	30,000
Special charges for fitting, etc.	3,000
Total	76,149

The total of the figures should agree with the total of the charges in the trading and profit and loss account.

The following examples will show the difference between placing the indirect charges on the weight of the bottle and on the journey or time occupied by a full set of hands in their production respectively, and I think the method of charging on the journey is better than on the productive labour cost. Assuming that the £15,000 on bottles produced 3822 tons, would give £3 18*s*. 6*d*. per ton.

Quantities produced by set of workmen.		Wt. of product.	*A* Indirect charges. On Weight at £3 18*s*. 6*d*. per ton.	Per gross.	*B* Indirect charges. On journeys worked @ £2 per journey.	Per gross.
80 dozen	24 oz.	0·640 ton	2 10 2¾	7/2·1	2 0 0	5/8·57
110 ,,	16 ,,	0·590 ,,	2 6 3¾	5/ 0·65	2 0 0	4/4·36
130 ,,	8 ,,	0·350 ,,	1 7 5¾	2/ 6·46	2 0 0	3/8·30
140 ,,	6 ,,	0·280 ,,	1 1 11¾	1/10·63	2 0 0	3/5·14
200 ,,	2 ,,	0·132 ,,	10 4½	7·47*d*.	2 0 0	2/8·80

It is quite obvious that with the same set of hands making the different sizes of bottles on different days, the indirect charges, rates, taxes, etc., could not vary from £2 10*s*. 2¾*d*. for the day to 10*s*. 4½*d*. If this method of costing were adopted, large orders might be received for the smaller size bottles, and if the whole factory were put on to these small bottles, and the cost based on the weight, a very serious loss would result, whereas if the charges are placed on the journey it would not make any difference for what size bottles orders were accepted, as each journey would bear its proper portion of the charges.

Output.

The weight of the output should be carefully kept, and to save labour and duplicated entries I advocate a column in the wages book, as all bottles which are saleable are entered in the wages book. By far the best way is to make a ready reckoner on the percentage of a ton basis, and the number of bottles made are then cast out, as indicated by the following example:—

Number of of bottles in dozens.	Working weight per bottle.	Total weight in tons.
311	22 oz.	2·289
960	12	3·850
181	18	1·090
743	19	4·721
215	22	1·582
218	23	1·678
168	21	1·180
711	17	4·045
52	10	0·173
723	11	2·660
790	18 oz.	4·756
1,033	12	4·142
828	19	5·265
205	23	1·578
244	21	1·715
860	17	4·893
58	10	0·193
889	11	3·272
933	18	5·617
	Total	54·699

In this way the weight output of each tank or shop is obtained separately. At the end of the period the total of these figures should be approximately the same as the total in column 7 in the first example. To get the cost of any particular bottle, the average drawings per journey of that bottle are required. The following examples will fully explain the method.

Cost of Individual Bottles.

	Total Cost.			Cost per gross.		
	£	s.	d.	£	s.	d.
Quarts, 24 oz. weight.						
Average drawing 80 doz. @ 24 oz. 0·640 ton @ £7 7*s.* 3½*d.*	4	14	3			
Charges	2	0	0			
Bottle hands' wages	5	0	0			
	11	14	3	1	15	1½
16 *oz. weight.*						
Average drawing 110 doz. @ 16 oz. 0·590 ton @ £7 7*s.* 3½*d.*	4	6	10			
Charges	2	0	0			
Bottle hands' wages	4	15	0			
	11	1	10	1	4	2½
8 *oz. weight.*						
Average drawing 130 doz. @ 8 oz. 0·350 ton @ £7 7*s.* 3½*d.*	2	11	7			
Charges	2	0	0			
Bottle hands' wages	4	12	6			
	9	4	1		17	0
6 *oz. weight.*						
Average drawing 140 doz. @ 6 oz. 0·280 ton @ £7 7*s.* 3½*d.*	2	1	3			
Charges	2	0	0			
Bottle hands' wages	5	5	0			
	9	6	3		15	11½
2 *oz. weight.*						
Average drawing 200 doz. @ 2 oz. 0·132 ton @ £7 7*s.* 3½*d.*		19	5			
Charges	2	0	0			
Bottle hands' wages	5	10	0			
	8	9	5		10	2
Cost of 2 oz. bottles with common mouth, as above					10	2
Add glass stoppers and cork rings						
Wages, washing and fitting, and allowance for breakages					3	6
Total cost per gross of fitted bottles					13	8

Bottles which have to be fitted or treated differently from ordinary common bottles will require to have the special charges added, as in the last example given.

To emphasise the difference in the two methods referred to, I give the same illustrations as previously used, but with the indirect charges shown on the weight.

All Charges on Weight except Bottle Hands' Wages.

	Cost per ton.			Cost per drawing.			Cost per gross.		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
24 oz. bottles.									
Average drawing 80 doz. 0·640 ton @	7	7	3½	4	14	3			
Charges ...	3	18	6	2	10	3			
Bottle hands' wages ...				5	0	0			
				12	4	6	1	16	8
16 oz. bottles.									
Average drawing 110 doz. 0·590 ton @	7	7	3½	4	6	10			
Charges @	3	18	6	2	6	4			
Bottle hands' wages ...				4	15	0			
				11	8	2	1	4	10
8 oz. bottles.									
Average drawing 130 doz. 0·350 ton @	7	7	3½	2	11	7			
Charges @	3	18	6	1	7	6			
Bottle hands' wages ...				4	12	6			
				8	11	7		15	10
6 oz. bottles.									
Average drawing 140 doz. 0·280 ton @	7	7	3½	2	1	3			
Charges @	3	18	6	1	2	0			
Bottle hands' wages ...				5	5	0			
				8	8	3		14	5
2 oz. bottles.									
Average drawing 200 doz. 0·132 tons @	7	7	3½		19	5			
Charges @	3	18	6		10	4½			
Bottle hands' wages ...				5	10	0			
				6	19	9½		8	4¾

It will be observed that in the 2-oz. bottle there is a difference of nearly 17½ per cent. in the cost by the two methods, the charges on weight being obviously below actual cost.

The method described can be used by taking the aggregate figures where one method of working only is in operation, but where different systems of working are in operation at the same factory, for example, working on the flint house glory holes, ordinary style; working on the American system, working on the bottle house method, working on hand machines, working semi-automatic or automatic machines, certain charges will have to be subdivided and departmental costs kept.

For instance, the cost of moulds and tools, the upkeep of machines, power and compressed air for machines, and all charges not applicable to all the systems, must be kept distinct and apportioned accordingly.

The stock book should be kept, in which are entered all the bottles paid for as good and saleable, and credited with all the bottles sent away and invoiced. A monthly stock sheet can be extracted with little effort and without actually counting the stock. This should be checked with the actual stock at each balancing period.

HAMMERTON,
RED HILL,
CASTLEFORD.

IV.—*An Apparatus for the Accurate Calibration of Burette Tubes.*

By S. ENGLISH, M.Sc., A.I.C.

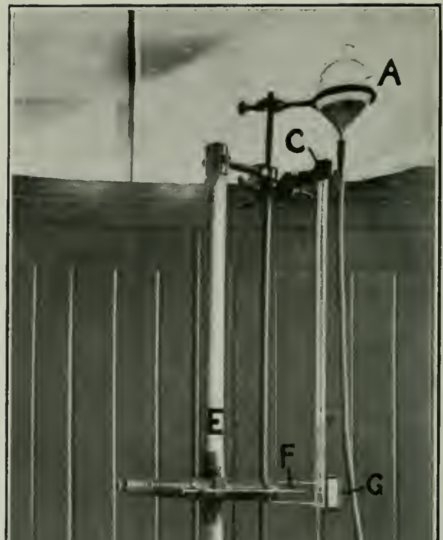
(*Read at the Sheffield Meeting, December 18th,* 1918.)

THE principle of the method described recently for the calibration of pipettes can very easily, accurately, and fairly quickly be applied to the calibration of tubes for burettes. Before describing the method it may be an advantage to restate two conditions which should be observed in the calibration of volumetric apparatus and of burettes in particular.

(1) The apparatus should be calibrated in the same way as that in which it is to be used. As pipettes and burettes, for example, are practically always used for delivering liquids, they should be calibrated by emptying, and not by filling into them a definite volume which it is assumed they will deliver.

Ordinarily, burettes are used for delivering liquids which wet the sides of the tubes, and on running out leave a film on the walls. They should therefore be calibrated in such a way as to leave this film behind after a definite volume has been withdrawn. If a filling process were used, the upper parts of the burette tube would be left dry, and hence false calibration marks would be obtained.

34^1



[To face p. 35.

(2) In the case of apparatus used for the delivery of liquids, the calibration should be done by using a liquid of the same type as those for which the apparatus is ordinarily employed, the time of emptying and the drainage period allowed being as nearly as possible the same as in ordinary use. If it is impossible to fix an approximately standard time for emptying and drainage, it is advisable to allow sufficient time for the drainage to be reasonably complete.

Since there is a difficulty in obtaining suitably sized tubes to make 50 c.c. burettes with a perfectly uniform bore from end to end, it is essential to calibrate the length in sections and then divide up these sections separately. In the method of calibration described, a 10 c.c. pear-shaped pipette is fitted with a 3-way tap so that the volume from the tap to a mark on the capillary is very exactly 10 c.c. when the temperature is 15°. If water were used in the calibration of a tube for a 50 c.c. burette, this 10 c.c. bulb would have to be filled and emptied five times, and unless great care were taken, a small drainage error might creep in each time, and though one small error might not be sufficient to spoil the calibration, the five possible errors might add up to an appreciable quantity. To overcome this possible source of error, the burette tube is connected through a tap tube to an elevated mercury reservoir (*A*), and mercury only is measured out into the 10 c.c. pipette. On emptying the latter the mercury runs out completely, leaving no drainage whatever.

The tube to be calibrated, after being well cleaned and having passed the necessary preliminary tests, is fitted on to the rubber stopper (*B*) and into the clamp (*C*). The tap (*D*) is opened, and the tube nearly filled with mercury, care being taken not to enclose any air bubbles along the sides of the tube. About 1 c.c. of water is then poured on to the top of the mercury, so that on filling the small pipette exactly 10 c.c. are withdrawn from the burette tube without any possibility of a drainage error creeping in, and the layer of water, in falling down the tube, leaves the sides wet, just as in ordinary use. Thus we have a very accurate method of withdrawing consecutive quantities of 10 c.c.

It is no use, however, having an accurate method of doing this unless there is coupled with it an equally accurate method of marking the position of the water meniscus. If this is left for the ordinary works graduator to do with his eyes and hands unaided, it would be very easy for a mark to be placed 1 mm. from its correct position, because of a parallax error, or unsteadiness of the hand, or general carelessness. In order to overcome these sources of error, a short focus telescope working up and down the stand

(*E*) by a rack and pinion can be brought up so that the cross-wire rests on the magnified image of the meniscus. With a magnification of three or four diameters, it is easy to get the position very exactly without any possibility of a parallax error. Having got the meniscus on the cross-wire, the position is marked on the tube by the needle (*F*), which can be moved forward and outward, but cannot turn round, nor can it move up and down. The needle, which is pivoted near the front of the telescope tube, is pressed forward till its point meets the tube, and is then moved horizontally, thus making a mark on the tube in whatever medium is being used for the purpose. By this means, it is absolutely impossible for a worker to place a mark in a wrong position when once the cross-wire has been brought to the meniscus.

Those who are familiar with the accurate reading of burettes know that the reading of the position of the meniscus varies as the background is changed; hence it is essential in calibrating, as in using, burettes always to use the same background. Further, when using a telescope for fixing the position of a magnified meniscus, it is not only necessary to use the same screen or background, but also that this screen should be kept the same distance away from the tube, as a variation in the distance between the screen and the tube very appreciably affects the apparent position of the meniscus. In order to prevent any error due to this cause, a screen (*G*) is mounted on a framework which is secured to the telescope tube, and thus a permanent background is provided at a fixed distance behind the tube that is being calibrated. If the apparatus is arranged facing a window or a light, a screen of ground glass gives a uniform light background on which the meniscus shows up as a sharp, black crescent. If the apparatus faces away from the light, then a white, opaque tile forms a very satisfactory background.

A point that must receive attention in designing such an apparatus for regular works use is that the burette tube must be perfectly parallel to the pillar on which the telescope moves, and must always be the same distance from it, otherwise as the water meniscus is brought down the tube it will have to be continually brought into the field of view, and continual refocussing will be necessary. These essentials can best be obtained by mounting the telescope and the burette tube clips on stands which are fixed perfectly parallel, and are fastened to the same base. Then whenever a tube is placed on the rubber stopper and in the top clip, it will automatically come to a fixed position, and give a meniscus in the middle of the field of view and in good focus.

As a test of the speed and accuracy of this apparatus, a tap with a very fine outlet was sealed on to a cleaned glass tube with a line of Indian ink drawn from end to end. This tube was then calibrated in five sections of 10 c.c. each. In the calibration, the time allowed for the filling of the pear pipette and the drainage of the water from the sides of the tube for each 10 c.c. section was forty-five seconds, and the whole operation for the five sections was completed in rather less than five minutes. The degree of accuracy of the calibration of this burette was tested by filling with distilled water, and emptying 10 c.c. at a time, giving forty-five seconds' drainage and using the cathetometer telescope to get very accurate readings. The weight of water delivered from each 10 c.c. section is given in the following table.

Temp. of water, 14·0°.

Correct wgt. of 10 c.c. at 14° = 9·9814 grams.

Weight of bottle with water.		Weight of each 10 c.c.	Error.
—	27·5903 gm.	—	—
+10 c.c.	37·5770	9·9867 gm.	0·0049 c.c.
20	47·5575	9·9804	0·0014
30	57·5362	9·9788	0·0030
40	67·5198	9·9836	0·0018
50	77·4992	9·9794	0·0028
	Mean	9·9818 g.m.	

Taking the maximum error as 0·005 c.c., the method is shown to be accurate to 1 part in 2,000 over any one section, and to 1 part in 10,000 over the whole length of the burette.

DEPARTMENT OF GLASS TECHNOLOGY,
THE UNIVERSITY, SHEFFIELD.

V.—*Bottle-glass and Glass-bottle Manufacture.*

By W. E. S. TURNER, D.Sc.

(*Read at the Sheffield Meeting, December* 18*th*, 1918.)

THERE has at times been conveyed to the author an impression that, despite the importance of the glass bottle industry in this country and the loyal support which its members have given to the present scientific movement, there has as yet been little done for it during the past three or four years, and that the various researches carried out in this country and the subjects discussed before this Society have been directed in a very large measure to assist the chemical and scientific glass trade only.

There is, naturally, much truth in this statement, since it has been necessary for scientific effort to be concentrated on those industries which did not previously exist and from which certain goods must be obtained for the prosecution of the war. But when this is admitted, it must still be pointed out that many of the results achieved are capable of application equally to bottle glass as to scientific glass manufacture; that if, previously, the examples drawn on for discussion have concerned chemical glass, it is not so very difficult to choose bottle glass for illustration and derive similar conclusions. Moreover, the principles of furnace management and of annealing apply similarly to all types of glass.

It appeared to the author, however, that there might be an advantage in attempting to set out a few results of special application to the glass bottle industry.

The term "bottle" is a fairly comprehensive one, embracing vessels of all sizes and shapes, narrow and wide mouth. Despite the fact that the most important section of the glass industry in this country is that of bottle-making, there are some types of bottle as yet not produced here. Bottles for syphons furnish one important illustration. Yet there is a very big demand for such bottles, and the author has several times been approached with the view of getting them manufactured in this country. Just before the beginning of the meeting, a member of the audience approached the author and stated that his firm had been in the habit of purchasing syphon bottles to the value of £15,000 per annum, and raised the question as to whether it would not be possible to produce them at home.

In case any British manufacturer might wish to take up the manufacture, the following information may be of value. Samples of the syphons imported from Bohemia have been analysed, and in column 1, Table I, the result of the analysis is stated, and in column 2 a likely batch composition, calculated on the supposition that the sodium oxide was all added initially as soda ash.

TABLE I.

Composition of a Soda-water Syphon, imported into Great Britain from Bohemia.

1.

Percentage composition of glass.

SiO_2	75·34
Al_2O_3	0·45
Fe_2O_3	0·30
CaO	6·83
MgO	0·21
Na_2O	13·78
K_2O	3·41
Sb_2O_3	trace.

2.

Probable simplest equivalent batch.

Sand	75·5 parts.
Limespar	12·5 ,,
Soda ash	27·6 ,,
Antimony oxide	0·5 part.
Manganese	(as needed).

In Table II is quoted another batch mixture which has been recommended for use in Germany for the same purpose.

TABLE II.

Actual German Batch Mixture used for Syphon Bottles.

Sand	100	parts.
Soda ash	33	,,
Limespar	22	,,
Saltpetre	3	,,
Saltcake	1	part.
Manganese	0·3	,,
Antimony oxide	0·3	,,
Cobalt oxide	0·0005	,,

A similar glass for the purpose could be obtained by the use of the batch set out in Table III. This batch has been recommended by the author for melting in skittle pots in coke-fired furnaces, and has given satisfactory results.

TABLE III.

White Glass for Bottles.

Readily Melted in Simple Coke-fired Furnace.

Sand	100	parts.
Soda ash	33	,,
Limespar	18	,,
Soda nitre	4	,,
Arsenic	0·2	part.
Manganese	0·2	,,

DURABILITY AND PRODUCTION.

Although there are various phases of the subject of bottle glass and bottle manufacture which all need discussion, the author considered that in the present paper he might usefully make his contribution under the two headings of quality and quantity, or durability and production.

The former property deserves more attention than it usually receives, for, although it may be laid down as a general principle that no glass is worth manufacturing which will not keep, the rule is not infrequently violated. It is a great temptation, undoubtedly, when the furnace is not working satisfactorily, and the metal must be got ready for the bottle-makers, to soften the batch by a very liberal addition of alkali. Not infrequently examples of this treatment come into the author's laboratory. For example, some time ago some specimens of feeding-bottles were sent for inspection. When sterilised by boiling in water, a process to which such bottles should be capable of being submitted, both large general cracks and splintering over very small circular areas took place. The conclusion drawn was that the metal had contained too much alkali, and analysis of the glass confirmed this conclusion. Samples of feeding-bottles from a second source recently received have possessed the same fault.

Nor is the fault always due to the necessity for desperate measures in getting metal ready. The author has found, in connection with the various types of automatic feed devices now coming into use, a great tendency to use very soft batches. The nature of the device, indeed, calls for a soft batch; but the engineer appears in many cases to have been working without collaboration with the chemist, and to have come perilously near, in some instances, to making a non-durable glass.

In most cases, the trouble has been found in connection with flint glass, common bottle glass being comparatively immune from the defect. The very impurity of the materials used in the production of the latter does, unwittingly on the part of the manufacturer, lead to durable bottles. Thus the sand usually employed contains notable proportions of alumina, which gives durability. The presence also of a sensible proportion of iron oxide assists in the fusibility, whilst tank-furnace temperatures rule sufficiently higher than pot furnaces as to make it possible to increase the proportions of sand or of limestone, or of both, and both silica and lime give durability to the glass. The increased durability and cheapness of the glass produced is a strong argument in favour of the use of high-temperature furnaces for glassware other than bottles.

Tests for Durability of Bottle Glass.

Some method of controlling the durability of glass bottles produced should, for the reasons stated above, be in operation in every works, particularly in those manufacturing bottles for medicines and pharmaceutical preparations; but milk-bottles, feeding-bottles, and white flint bottles generally should also be inspected.

In Table IV are set out some simple methods of testing. Their suitability for the purpose of testing medicinal bottles will be evident, since the substances used in tests 1—3 are themselves medicines, very susceptible to poor glass. In all these cases the medicine is acted on by the alkali taken from the bottle, with the precipitation of a sediment. Such a bottle used for storing a medicine might change the character of the latter so as to spoil it. In test 4 the alkali colours the phenolphthalein pink.

TABLE IV.

Tests on Durability of Medical Bottles.

Before test, bottles to be cleaned either (*a*) by sterilising in steam for half an hour, or (*b*) by washing first with dilute acetic acid and then thoroughly with water.

Tests.

After standing twenty-four hours with the following solutions:—

1. 1—2 per cent. of morphine hydrochloride should be colourless, or at most pale yellow.
2. 0·5—1 per cent. of strychnine nitrate solution should cause no separation of crystals.
3. 1 per cent. of mercuric chloride solution should show no precipitation of coloured oxide.
4. Water containing a few drops of phenolphthalein should not develop a pink colour when allowed to remain in a corked bottle for twenty-four hours.

A better method, wherever it can be employed, consists in subjecting the bottle to the action of water (and steam) under pressure in an autoclave. A measured quantity of pure water is placed in the bottle, the latter transferred to the autoclave, and the temperature raised to and maintained at 120° for two hours. The alkalinity of the water is subsequently determined by the amount of a solution of sulphuric acid of fixed strength required to neutralise it.

Table V affords some interesting comparisons. It contains the results of tests on bottles received from different firms, each set from one source being bracketed. In each case the bottle was filled with water and the amount of alkalinity ascertained by titration with $N/100$-sulphuric acid, using methyl-orange as indicator.

The bottles were not all of the same size, hence the volume is stated in most cases, in others the internal area of the surface exposed to the action of the water.

Table V.

Durability of Bottle Glass.

Bottle No.	Volume.	Internal area.	Total alkali set free.
1 (amber)	178 c.c.	—	7·4
2	105 ,,	—	5·6
A	246 ,,	282 sq. cm.	2·2
B	296 ,,	390 ,,	23·0
C	278 ,,	318 ,,	2·9
D	240 ,,	272 ,,	2·4
E	156 ,,	200 ,,	2·1
I	227 ,,	—	263·7
II	235 ,,	—	157·5
III	362 ,,	—	71·8
IV	115 ,,	—	67·1
V	240 ,,	—	153·8
VI	154 ,,	—	113·2
a (batch)	—	100 ,,	1·54
b (cullett)	—	100 ,,	2·27

Of the bottles (*a*) and (*b*) coming from the same firm, (*a*) was made from the batch mixture given in Table III, whilst (*b*) was made from cullett (of unknown composition). Both samples are good, but (*a*) is distinctly better.

All the bottles in the first, second, and fourth sets are good except *B* in the second set. All those in the third set are bad. After the action of water on them they were covered with a white film. They contained far too much alkali in their composition to give a permanent glass.

Seeing that the author has laid so much emphasis on the need of avoiding excess of alkali in a glass, manufacturers may not unnaturally ask what limit is allowable. The answer depends on the nature of the glass and the character of the other constituents. Assuming that, as is general in bottle-making, the glass is simply of the lime-soda type, the proportion of soda ash in the batch should not exceed about 28 per cent. Of the two following batches (Table VI) actually tested in this department, the first yields a glass which is not good, whilst that from (2) is satisfactory; (3) is still better.

Table VI.

Unsatisfactory and Satisfactory Batches.

	(1)	(2)	(3)
Sand	63·19	63·26	62·86
Limespar	7·02	8·79	15·72
Soda ash.........	29·78	27·94	21·42

Factors Governing Production.

The rate of production of glass bottles depends on two main factors, namely, on the mode of operation and on the character of the glass worked. Whether the mode of operation be by handworking or by semi- or fully-automatic machines, the importance of the right type of glass is ever present. For each particular type of machine a suitable, or at any rate the most suitable, batch should be investigated.

Now the working property of a glass depends on its composition, since the latter influences the softening point and the speed of setting. The maximum proportion of any one constituent which may be present in a workable glass varies with the worker, since some men and some machines can cope with a hotter glass than others, and it is obviously an advantage to be able to work very hot glass if it is one that readily stiffens. It is possible, however, to state certain general limits for easy working, and in regard to glasses of the lime-soda, magnesia-soda, and alumina-soda type Table VII indicates these limits as ascertained in the author's Department.

Table VII.

Lime-soda glasses	14 per cent. lime (CaO).
Magnesia-soda glasses ...	9 per cent. magnesia (MgO).
Alumina-soda glasses ...	9 per cent. alumina (Al_2O_3).

These amounts of oxide stated are the proportions in the finished glass, and with a glass of the type known as a tri-silicate. It is quite possible to increase these amounts either (1) by addition of other oxides; (2) by reduction in the proportion of silica. This will be obvious from some of the figures given later (see pp. 44, 45).

The workability of a glass is most readily expressed by the property of viscosity or its opposite, namely, fluidity. This property will now be more fully dealt with, although as yet the information, so far as it is applicable to glass, is scanty.

The Influence of Different Constituents on Viscosity.

1. *Lime.*—The importance of the composition is brought out in the considerable variations of lime content which bottle batches used in different works show. Lime is a valuable constituent in glass, because it imparts tensile strength and better conductivity for heat; and, because it is also cheap, it is used as largely as possible. It has a further advantage, especially for handworking and for

some types of machines, in that the glass containing it sets very quickly.

Of the two following batches (Table VIII), which both yield a good glass, (2) contains more than 50 per cent. more lime in proportion to soda-ash, and in consequence will, at temperatures between 1200° and 1300°, be softer or more fluid than the other, but will, on the other hand, set quicker.

TABLE VIII.

	1.	2.
Sand	1000	1000
Soda-ash	310	300
Limespar	277	450
Arsenic	—	7

It is presumably this property of quick setting which led to the adoption of the following batch for an Owen's machine working in Germany.

TABLE IX.

German Bottle Batch for Owen's Machine.

		Composition of		
	Batch.		(1) The sand.	(2) The limestone
Sand	1000	SiO_2	93·72	14·98
Limestone	554	Al_2O_3 Fe_2O_3	4·51	6·77
Saltcake	300			
Fluorspar	60	CaO	1·37	26·31
Powdered coal	24	MgO	trace	13·22
Manganese	42	Loss on ignition	1·23	38·72
Iron oxide	13			

The proportion of lime in a batch which can be melted is surprising. In the author's Department the following batch, omitting the minor constituents, such as small amounts of iron and alumina, has been melted and worked, although not readily, the metal being like oil.

TABLE X.

Batch for High Lime Glass.

Sand (silica)	42
Limestone ($CaCO_3$)	80
Soda ash	20

In commercial practice, the percentage of lime in bottle glass may be considerable, as illustrated by the following data in Table XI.

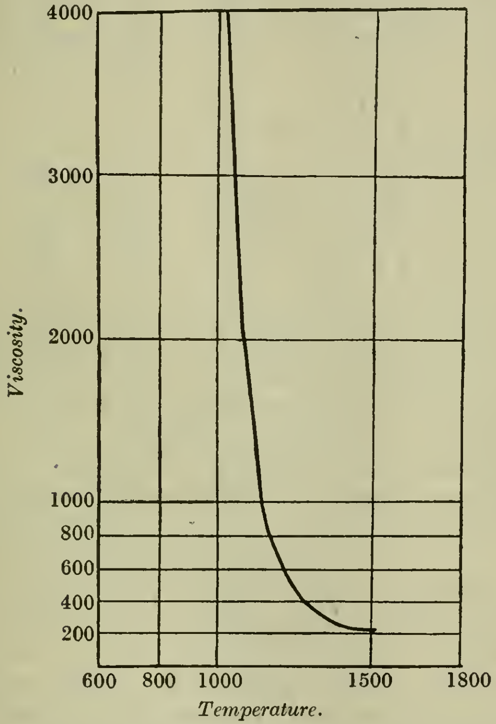
TABLE XI.

Source of Bottle.	Composition.							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO
Trelon	62·21	1·16	5·50	22·98	—	5·69	1·91	—
Cognac	62·54	4·42	1·20	20·47	5·41	4·73	0·94	—
Bechelbach	65·57	3·34	2·53	23·42	—	4·86	2·72	0·28

The compositions stated in the above tables are those of the finished glasses.

From practical experience, as already remarked, the effect of lime is to yield a glass the viscosity of which is high until a fairly high temperature is attained, and then falls rapidly, becoming very limpid. Practical experience is borne out by measurements of viscosity. The results with a glass of the following composition:—

FIG. 1.

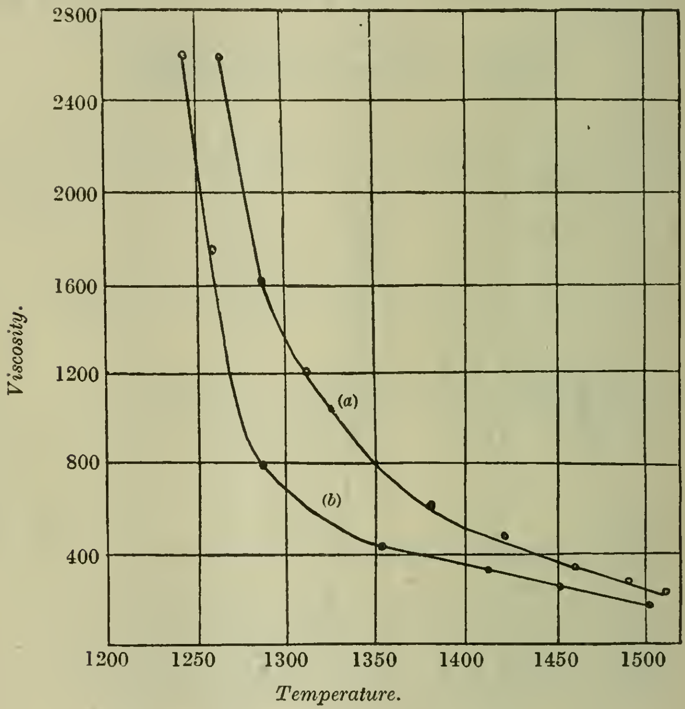


SiO_2	72·0 per cent.
Al_2O_3	3·0 ,,
CaO	5·5 ,,
Na_2O	15·0 ,,
K_2O	4·5 ,,

is shown graphically in Fig. 1.* The steepness of the curve between 1050° and 1200° indicates a very rapid diminution in the viscosity. That is to say, the working range for a high lime-containing glass is small. Within a range of about 150°, the metal on the one hand may be too stiff, on the other too soft to be worked.

2. *Magnesia.*—This constituent in some respects resembles lime, as, for example, in the range of temperature over which it can be worked. Illustration of this is seen in Fig. 2, curve (*a*), which represents the viscosity of a glass † (or slag) having the percentage composition SiO_2 52, CaO 48. In curve (*b*) the viscosity is that of a glass (or slag) with SiO_2 52, CaO 28, MgO 20.

FIG. 2.



It will be noted that at any temperature between 1250° and 1300° the viscosity of the magnesia-containing glass is materially less than the lime-glass, but above 1300° the difference diminishes. In other words, magnesia, if substituted for lime, softens the glass distinctly and gives somewhat wider working limits.

---

* K. Arndt (*Zeitsch. Chem. Apparaterkunde*, 1908, 3, 474).

† A. L. Feild (*Trans. Faraday Soc.*, 1917, 13, 3).

Our experience of glasses made in the department is that magnesia-soda glasses with considerable proportions (10 per cent.) of magnesia become stringy in working. Those in which magnesia is present with lime are tough, and do not set so quickly as lime-glasses.

Bottle manufacturers may aver that they do not use magnesia in their batches. Manufacturers of common bottles frequently do use it, however, although they may not be aware of the fact. Some of the limestones used are dolomitic ($CaCO_3$, $MgCO_3$), and the magnesia is introduced in this form.

3. *Silica and Alumina.*—Some quantitative data obtained for slags enable certain conclusions to be drawn in regard to these constituents. Table XII states the softening temperatures and viscosities of two mixtures.*

TABLE XII.

Composition.			Softening temperature.	Viscosities at		
SiO_2	Al_2O_3	CaO		1400°	1450°	1500°
43·56	9·48	40·18	1279°	1000	680	480
18·30	35·30	31·24	1410°	750	410	230

Although these data are scanty and the mixtures in no way resemble bottle glass, certain conclusions are permissible. The first is that a high softening point does not necessarily mean difficult working in the case of a glass, for although the slag with high alumina has the higher softening point, the viscosity is very distinctly less than that of the high silica slag. Further, a highly siliceous glass appears to be stiffer than one with high alumina, and its plasticity does not change so rapidly. Obviously, a glass which is too soft could be stiffened by the addition, or increase in the amount, of silica (sand) or alumina.

It has already been remarked that 9 per cent. of alumina in a glass is approximately the limit in an alumina-soda glass. The limit depends, however, on other constituents present. Of the three following foreign bottle glasses, it will be seen that only the first contains as low as 9 per cent. of alumina.

TABLE XIII.

Source of bottle.	Composition.					
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MnO	Na_2O K_2O
Dresden	63·98	8·90	2·15	17·46	—	7·30
Gerresheim......	64·06	12·00	1·42	14·50	—	7·88
Wirges	60·20	14·92	2·09	12·20	1·27	9·13

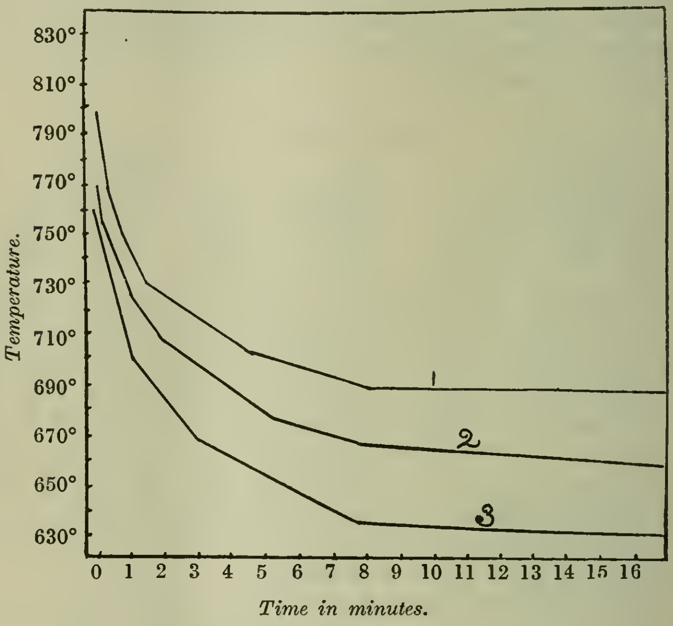
---

* A. L. Feild (*loc. cit.*).

The first has been worked into bottles in the author's Department fairly readily; the second is also workable with a hot furnace. The third was very stiff, and would require a tank furnace working at a higher temperature than usual.

4. *Soda.*—Practical experience shows that increasing the proportion of soda (alkali) softens a glass. Actual measurements of the effect on the viscosity of molten glass remain yet to be made. Some determinations made by ascertaining the rate of extension of a heated glass rod placed in a vertical position and weighted at one end have been carried out, and Fig. 3 illustrates the relationship obtained between workability and proportion of soda at different temperatures.*

FIG. 3.



The three curves in Fig. 3 show the effect of increasing the percentage of soda on the rate of extension (that is, on the softness) of the glass rods. The compositions of the glasses were:—

	SiO_2	Na_2O	K_2O	Al_2O_3 Fe_2O_3	CaO	MgO
1	70·08	19·09	0·87	1·61	7·49	0·21
2	67·68	21·69	0·82	1·92	7·19	0·25
3	65·36	24·53	0·95	1·52	7·06	0·23

---

* von V. Vesely (*Sprechsaal*, 1911, **44**, 457).

It will be seen that with the glass containing the highest amount of soda, extension begins at the lowest temperature, and that the rate of increase of softening is slowest with this glass (3).

Reviewing the evidence mentioned in this section concerning the variation of viscosity with composition, a summary may be drawn up as follows (Table XIV):—

TABLE XIV.

Variation of the Viscosity with the Composition of Glass.

Soda.—(*a*) Makes glass more fluid.
(*b*) Reduces rate of setting.
Potash.—Resembles soda, but less effective weight for weight.
Lime.—(*a*) Makes glass less fluid at low temperatures, but more fluid at high.
(*b*) Increases rate of setting.
Magnesia.—(*a*) Makes glass less fluid.
(*b*) Increases rate of setting, but not to the same extent as lime.
Alumina.—(*a*) Makes softening temperature high.
(*b*) Viscosity at high temperature not high compared with lime or silica.
Silica.—Causes high viscosity which does not change rapidly.

The above table will, the author hopes, give some assistance to manufacturers when endeavouring to modify their batches to meet new conditions.

DEPARTMENT OF GLASS TECHNOLOGY,
THE UNIVERSITY, SHEFFIELD.

OUR IDEAL.

AN APPEAL FOR CONTINUED CO-OPERATION.

PRESIDENTIAL ADDRESS. BY S. N. JENKINSON, M.B.E.

(*Delivered at the Sheffield Meeting, June* 18*th*, 1919.)

OUR Society started just two and a half years ago, and I would like us to consider if we have lived up to the expectations of our parents. As far as numbers go, we have undoubtedly done well; perhaps, even, exceeded the most optimistic of our estimates. Where now do we stand? and what now is our ideal?

The time is perhaps opportune for us to ask ourselves these questions, for to-day we are finishing a session's work. Mr. Frank Wood, who with Dr. Turner brought us into the world, is no longer our President, and we thus suffer the first break-away from the hands that have steered us so successfully through difficult times; the first break-away from those who have put us on our feet. As I have been honoured by you to serve as your President, I find myself confronted by the questions which I have expressed.

Our chief war has now been brought to a conclusion, and business will gradually become more normal.

This is a further reason for us to examine our attitude towards our Society, even to ask ourselves what, in the first place, induced us to join it. It may possibly be that we joined in the hope of learning something at somebody else's expense; possibly because it was the thing to do. Honestly, our Society does not exist for either of these purposes.

We have excellent papers, and our meetings are well attended, yet I feel that many attend with the sole expectation of learning something, and seldom with the idea of imparting anything.

The ideal of our founders was, I believe, that we should help one another; every member should not only receive help, but should give it. We meet together for an exchange of ideas, for frank discussion of our many difficulties. Papers which are read should not be treated as sermons, but simply as a record of the experiences of a member, given to encourage other members to state their own experiences and difficulties. We are a co-operative Society, initially called together in a time of great difficulty, and our ideal was to help one another. We should on no account lose sight of this, which is our first and foremost ideal.

Many of us consider we have the most wonderful and awful secrets. If, however, we acted up to the ideal of our Society we would tell one another our secrets, when probably we should be startled to find that our pet secrets were also the pet secrets of others. There is nothing more disastrous to progress than secrecy, and the best work that we can do is to keep on breaking down these barriers at an even faster rate than we have done in the past.

Mystery and secrecy are the refuge of the ignorant; one has only to deal with Government Departments to realise this. In a Society like ours there are bound to be shades and differences of opinion. Indeed, differences are all to the good; they are a sign of active interest, a sign of health. If now I turn to our accomplishments, I may ask by what standard we can judge our success. Some will say by the number of members, others by the attendances at meetings; yet others by the quality of our papers and our JOURNAL. All these answers are correct; but I would go further, and suggest that we judge our success by the amount of help that we can and do give to one another.

In our war with the Central Empires we received a lesson that we must never forget. It was the value of co-operation, co-operation in the widest possible sense of the word, in small things as in big things. Until close co-operation was obtained, or, shall we say, until there was complete unity of effort—and it was a great effort—we made little progress against our enemies.

Now, the members of the glass industry must co-operate. I do not mean financially only, but in the multitude of details that go to make up its everyday life. It is only by complete unity of effort that we can hope to make the glass industry of Great Britain a world industry.

Our Society has achieved much, and will achieve more, if members keep in mind our ideal, come forward with questions, with criticism, with offers of papers, and with notes of unusual occurrences. In a trade such as ours, there is a constant stream of unusual occurrences, and if our Society could only obtain records of these, we should have a chance of solving many problems.

Closely connected with our ideal of helping one another is our membership problem. The larger our membership the more we can live up to our ideal and help one another. Again, more members means more cash, and, given all the goodwill in the world, we fail just when the cash fails. We are now more than 450 in number, and if every member between now and our next session introduces one new member, we should double our membership. All our present members must know someone who is not a member but ought to be. It should not be difficult for us, therefore, to double our membership in the next few months.

I doubt if all our members realise the standing that our Society has in other continents. Scientific journals in the U.S. frequently quote our JOURNAL. This is a great compliment to such a young publication; it is a great compliment to our Editor and his assistants. It is only right that all of us should recognise that the high position which our JOURNAL occupies in other countries is due to the ability as an Editor of Dr. Turner.

Fellow members, I thank you for electing me as your President. I will try to keep up the high standard that our first President has set. I am at your service whenever I can be of use to you.

In conclusion, I would ask you yet again to remember our ideal of helping one another.

On behalf of myself, your Council, and officers, I say to you,

If we please you, tell others.
If we don't, please tell us.

VI.—*The Examination of Optical Glass in Relation to Weathering Properties.*

By ALFRED VINCENT ELSDEN, OSWALD ROBERTS, and HAROLD SPENCER JONES.

CONSIDERABLE trouble has been experienced on account of the formation of a "film" or deposit on the surface of the glass components of optical munitions of war. This film or deposit made its appearance in varying periods after assembly of the instruments, in some cases developing in as short a time as a few weeks. The deposits appeared to be of two distinct types, one consisting of small, discrete globules easily visible with the aid of a low-power lens, the other composed of extremely minute particles forming a more or less uniform bloom over the surface of the glass, but sometimes recognisable under high magnification as having a globular structure. In certain cases these deposits increased to such a degree as rapidly to render the instruments unserviceable, and this was especially the case in hot climates. After cleaning, the glass surface did not appear to be affected, but the deposit did not evaporate when exposed to the air at the ordinary temperature, and although, when the glass was heated, the globules disappeared, a residue remained. The more obvious causes of such deposits are, of course, imperfect cleaning of the glass surfaces before assembly, volatile matter from the lubricant or interior blacking or bronzing material, "occluded" oily matter in the metal of which the bodies of the instruments were made, and oily or aqueous vapour present in the air at the time the instruments were sealed. But, even when all possible precautions had been taken to eliminate these sources of trouble, it was found that filming was still liable to occur; and it became evident that another factor, that is, the nature of the glass, would have to be taken into consideration.

The importance of this factor was proved by the following test among others. A number of binocular field lenses were prepared from different types of glass which had been previously examined by the tests to be described below. After these lenses had all been cleaned in the same manner, they were assembled into binoculars under identical conditions, and the instruments kept under observation. A globular deposit commenced to form within a week upon certain of the lenses, while others remained clean. The deposit gradually became more and more marked, and the other lenses remained unaffected. It was found that the lenses upon which the deposit had appeared were made from the glass which the authors' tests had shown to be susceptible to atmospheric influences.

It has long been recognised that glass is by no means unchangeable under ordinary atmospheric conditions, and although certain types are remarkably resistant to chemical attack, yet even the most resistant (with the exception of pure silica glass) are affected to some extent even by contact with pure water. Where chemical resistance is the chief consideration, it has been found possible by the use of certain ingredients to produce a glass which is so slightly attacked by water and ordinary reagents that it may be regarded for all practical purposes as stable under normal atmospheric influences. The problem in the case of optical glass is not so simple. Here the optical constants are of primary importance, and the difficulty is to obtain, in addition to certain prescribed optical properties, the necessary degree of permanence or stability.

The catalogue of optical glass issued by the well-known German firm of Schott gave the relative stabilities of the various types of glass manufactured by them. During the war, British optical instrument makers had necessarily to rely upon optical glass of British manufacture. No systematic tests had been made as to the stability of these glasses, and although from their general composition it might be concluded that certain types of glass would prove to be more stable than others, little or no information was available as to whether any particular type of glass would prove satisfactory when used in optical instruments. Until this question could be definitely settled, it was not possible to decide whether the trouble referred to above was due to causes directly within the manufacturer's control, such as careless cleaning, etc., or to the use of unsuitable glass. The necessity for some rapid means of testing glass in relation to weathering properties will be evident.

It is generally considered that the weathering properties of glass depend primarily upon its chemical composition, although the condition of the surface is also recognised as being an important factor. On account of the number of different materials used in the manufacture of glass, more especially in optical glass, where special physical properties are required, the problem of defining the qualitative and quantitative influence of any particular ingredient is extraordinarily complex.

With regard to the condition of the surface, it seems possible that not only the perfection of polish, but the method and materials used in obtaining the polish, may require consideration. The tests described below have, except where otherwise stated, been carried out on ordinary well-polished specimens. The question of the influence of polish upon weathering properties requires investigation, and will not be dealt with in the present paper.

In addition to the factors mentioned above, it is conceivable that weathering properties may be influenced by the previous thermal history of the glass. Some evidence pointing in this direction has, indeed, been obtained, but requires confirmation, and must be reserved for a subsequent communication. It will be clear that this factor may add materially to the complexity of the problem.

A number of methods have been proposed from time to time for testing the durability of glass. Heating in an autoclave at temperatures up to 180° with water has been widely adopted as a rapid stability test. The conditions are, however, so widely divergent from those obtaining in actual use that it is questionable whether the indications obtained are trustworthy for all types of glass.

Methods depending upon measurements of the solubility of glass in water and other media have been widely applied to the testing of resistant glass for chemical use, but are less applicable to optical glass, which is not usually available in a convenient form providing sufficient surface. Surface can, of course, be increased by powdering the glass, but this introduces uncertainty with regard to the area actually tested, and even if the powdered glass is carefully graded by sieving, the results are probably not comparable between glasses of different composition owing to possible variations in average shape of particles which may result from differences in brittleness, etc. Moreover, since in the case of optical glass one is concerned mainly with mechanically polished surfaces, it is obviously desirable to test such surfaces.

Careful review of all the methods proposed or in use of which information was available led to the conclusion that only one which reproduced as closely as possible practical conditions was likely to give trustworthy indications as to the durability of glass. Further attention was then directed to a paper by Zschimmer,* in which he states that he had compared the relative hygroscopicity of different glasses by heating polished specimens at 80° in air practically saturated with water vapour, and comparing the resulting deposits. He implied that glasses which under these conditions showed the development on the surface of liquid drops (permanent in the air at the ordinary temperature) or crystalline deposits, sooner or later showed a similar deposit if exposed to the atmosphere. No information was given of the apparatus used or of the details of the test, but the principle was so much in accord with what was considered desirable, inasmuch as it was carried out at temperatures not very far removed from that to which optical instruments might be subjected in tropical climates, that it was decided to investigate it with a view to its adoption.

At the same time, the fact that in Germany the iodoeosin value had been for some years the basis of the classification of glass in respect of durability, and the high reputation of German optical instruments, rendered an investigation of this test also desirable.

The Iodoeosin Test.

The iodoeosin test is so well known in principle that a detailed description of it is quite unnecessary here. The method adopted by the authors of testing both the freshly-broken surface and a broken surface after "weathering" for seven days in moist air at 18° is precisely that described by Mylius,† and the principles of the test have been fully dealt with by the same author.‡ It may be said that, provided a good, clean fracture of suitable area could be obtained and the conditions prescribed by Mylius faithfully observed, no difficulty was experienced in obtaining satisfactorily concordant results in duplicate tests. As pointed out by Mylius,* the iodoeosin test on a freshly-broken surface may give misleading results in the case of complex or heavy optical glass, and although as a matter of interest this test has been invariably carried out on all the glasses tested by the authors, they consider that it is the test upon the broken surface after "weathering" for seven days at 18° upon which most reliance is to be placed. It is believed that the Reichsanstalt uses the "weathered" iodoeosin value exclusively for its hydrolytic classification of glass.

---

* *Zeitsch. Elektrochem.*, 1905, **11**, 629.

† *Silikat-Zeitschrift*, 1913, **1**, pp. 2, 25, 45.

‡ *Zeitsch. anorg. Chem.*, 1910, **67**, 200.

The "Dimming" Test.

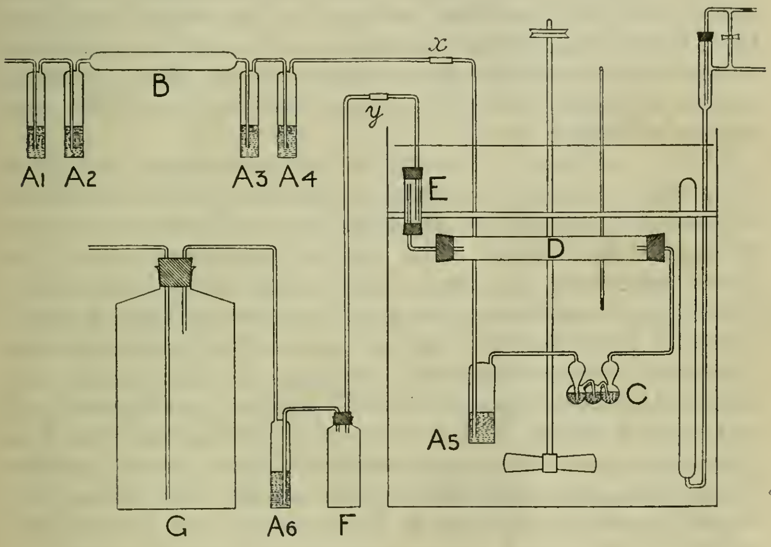
The first experiments with this test were made with somewhat crude apparatus, consisting of an air-bath through which passed a glass tube of about 1 inch internal diameter. The glass specimens were placed in this tube and a current of air, of which the moisture content was raised by previous passage through water, was drawn through it for varying periods of time. The air-bath was maintained at approximately constant temperature by means of a gas burner placed beneath it, and the moisture of the air current regulated by varying the temperature of the water through which it passed. The results were not satisfactory, the effect upon a glass known to be inferior in its resistant properties being by no means marked. It seemed probable that closer attention to detail was necessary, and an improved apparatus was devised by means of which the conditions, more especially the temperature and degree of saturation of the air current, could be more accurately controlled.

The accompanying figure shows in diagrammatic form the apparatus now in use with satisfactory results. As will be seen, it comprises a large thermostat, 15 inches in diameter and 18 inches deep, fitted with a sensitive toluene–mercury gas regulator, stirrer, and thermometer. The thermostat is fitted with an iron support for the purpose of holding in position the wide-bore glass tube, *D*, in which the glass specimens to be tested are placed. The air to be drawn through the apparatus passes first through the washing flasks, A_1 and A_2, into the tube *B* (12 inches long and 1⅛ inches internal diameter), which is tightly packed with moist, purified raw cotton. From *B* it passes through two more washing flasks, A_3 and A_4, into the thermostat. Within the thermostat the air passes first through a large washing bottle, A_5, and then through the Geissler bulb, *C*, into the tube *D*, which is 11 inches long and 1⅛ inches internal diameter. From *D* it passes through a trap, *E*, to a safety flask, *F*, and a wash-bottle, A_6, and finally to a large flask, *G*, which is connected to a water-pump.

---

* *Loc. cit.*

In order to avoid any possible contamination of the air passing through the apparatus with traces of strongly acid or alkaline vapours, the intake is carried through the wall of the laboratory to the outside air. The washing bottles and Geissler bulbs all contain distilled water. The cotton in *B*, the object of which is to remove dust particles from the air, is purified by prolonged extraction with water, alcohol, and ether, and is moistened with distilled water. The object of the trap *E* is to prevent any liquid (which may result from condensation of steam in the tube emerging from the thermostat) from running back into the tube containing the glass specimens. The tube *D* is thoroughly cleaned and steamed for a period of some hours before it is fitted to the apparatus. It has been found by weighing the Geissler bulbs before and after an experiment that the air becomes practically completely saturated with water vapour during its passage through A_5, so that there is no question that it attains complete saturation, at the temperature of experiment, during its further passage through the bulbs.



The water in the thermostat is kept thoroughly stirred throughout the test, and with suitable adjustment of the by-pass of the gas regulator the temperature variations need not exceed 0·05°, even when the test is carried out at 80°.

In carrying out an actual experiment, the apparatus is first fitted together and a current of air drawn through it for ten to twelve hours at the temperature of experiment in order to fill it with purified air and saturate the water in the wash-bottle with respect to carbon dioxide. It is then allowed to cool to the laboratory temperature, the passage of air being maintained throughout the cooling process. The whole of the apparatus within the water-bath is then removed bodily by disconnecting at x and y, the open ends of the tubes being at once closed by means of rubber caps.

The glass specimens should be preferably in the form of small plates with well polished surfaces, a convenient size being $1\frac{1}{2} \times \frac{7}{8} \times \frac{1}{8}$ inches. Smaller specimens can be used, but experience has shown that polished glass surfaces are not always uniformly affected in the test, and if the surface tested is too small the result may be misleading.

After a preliminary cleaning in the manner described below, the glass to be tested is subjected to a very careful visual and microscopical examination, any markings or imperfections observed being carefully recorded. The glass is then cleaned again. This is most important, as it will be obvious that if any foreign matter is left upon the surface of the glass, the result of the test may be vitiated. The cleaning is carried out in the following manner. The glass is first washed with a mixture of equal volumes of re-distilled alcohol and water to which 2 per cent. by volume of acetic acid has been added. It is then rinsed in distilled water and dried. The washing and drying are carried out with specially prepared linen cloths, and, after passing once rapidly over the top of a Bunsen flame to de-electrify it, the glass specimen is immediately inserted in the tube D, momentarily opened for the purpose.

The linen used for cleaning the glass is first boiled in a solution of pure sodium oleate in distilled water, then repeatedly in distilled water until the water remains neutral to methyl-orange, and finally in distilled water rendered faintly acid with acetic acid. The material is then freed from excess of liquid by wringing (being held for the purpose in tongs), and finally extracted in a Soxhlet apparatus with alcohol. After this extraction, the material is allowed to dry slowly in air as free as possible from dust.

It is important that neither before nor during the cleaning operations should the glass or linen be touched with the fingers more than is absolutely necessary As far as possible, the manipulation should be carried out by means of forceps and tongs, and the cleaned specimens should be placed in the apparatus immediately. In this way, contamination of the polished surfaces with dust and other foreign matter is reduced to a minimum, although the possibility of such contamination cannot be avoided altogether.

One or more polished quartz plates to serve as controls, similarly cleaned and treated, are inserted in the tube with the glass specimens.

The tube *D*, connected to the trap, washing bottle, and bulbs, previously removed from the water-bath, and now containing the glass specimen or specimens to be tested, together with the quartz controls, is then replaced in the water-bath and connected to the rest of the apparatus. The stirrer is placed in action, and the temperature of the bath is raised to that decided upon for the test. As soon as this is reached and the gas regulator is adjusted to maintain it, the air current is started by means of the water-pump. The quantity of air drawn through the apparatus, which is controlled by a tap not shown in the diagram, should not exceed one-third of a litre per hour.

When the test has proceeded for the desired time, the gas flame is extinguished and the temperature allowed to fall to 50° at the natural rate of cooling. The rate of cooling is then accelerated by conducting a slow stream of cold water to the bottom of the water-bath and siphoning out warm water from the upper part at such a rate that the level remains constant. The rate of cooling is so regulated that the temperature falls steadily from 50° to 2° below the laboratory temperature in about three hours. Efficient stirring of the water and the slow current of air through the apparatus must be maintained throughout the period of cooling. In this way, the moisture content of the air falls slowly and regularly with the temperature, and there is no condensation of liquid water on the quartz plates.

The tube *D*, together with the attached trap, etc., is then removed from the thermostat, as before, and the glass specimens and quartz controls examined *in situ*. The temperature being below that of the laboratory, no further cooling can take place and no condensation of moisture can occur within the tube during this operation. A more or less marked "dew" will usually be observed on the glass specimens, but none upon the quartz plates. Should the latter be "dewed," the test must be considered unsatisfactory, as this would imply either imperfect cleaning, impurities in the air current, or too rapid or irregular cooling, resulting in actual physical condensation of moisture from the saturated air, as distinct from the chemically initiated condensation on the glass specimens resulting from their hygroscopic nature. The glass specimens are then withdrawn from the tube and transferred as rapidly as possible to clean, dry test-tubes about 3 inches long and 1 inch internal diameter, which are immediately closed with rubber stoppers. In most cases, the "dew" visible to the naked eye disappears within a short time after transference to the closed dry tube, and it is useful to note the approximate time in which this takes place, because it is often the case that poor glass retains the "dew" longer than good glass.

When the "dew" has disappeared, the glass specimens are placed on a clean, dry watch-glass, and the polished surfaces are carefully examined. With a little practice and observation at various angles, especially against a dark background, a very slight degree of attack of the polished surface can be detected visually. The general appearance to the unaided eye is that of a slight "film" or bloom on the glass, which may be either uniform or irregularly distributed in patches. In the case of the glass being seriously attacked, the surface may even have the appearance of ground glass, and the specimen may no longer be transparent.

The specimens are then examined under the microscope, a $\frac{2}{3}$-inch objective giving a suitable degree of magnification. Under these conditions, the appearance of the specimens is very variable, and even on one and the same surface different effects may be observed. In many cases, the surface appears to be covered with very minute particles, the nature of which it is often difficult to determine even under higher magnification. These may be fairly uniformly distributed, giving the general appearance of a fine-grained surface to the glass, or they may be segregated in irregular areas, the surface between these areas being less affected. Larger particles having a crystalline outline may be seen either in clusters or as isolated features of the surface. In many cases, smaller or larger drops of liquid are to be seen, either irregularly distributed, collected in patches, or arranged in more or less definite lines, the latter probably indicating sleeks or shallow scratches filled in, or partly so, by the polishing process. In other cases, generally in those of poor glasses, when the surface is seriously corroded, a marked pitting action can be seen, the pits being surrounded by concentric rings of crystalline appearance. In most cases, any minute scratches or sleeks originally visible on the glass will be found to have become more pronounced.

There is no difficulty, after careful comparison of the glass before and after the test, in deciding whether the glass has been badly or only slightly affected, and after some experience a much closer discrimination can be made. In an attempt to give the results some quantitative value, the authors have classified as follows the glasses they have examined, according to the degree to which they were affected by the "dimming" test at 80° for thirty hours:—

Unaffected or only very slightly affected	1
Decidedly affected	2
Very seriously affected	3

In intermediate cases, the sign + or − is added, indicating that the glass was rather more or less affected than the general standard of the class. Thus a glass which cannot quite be graded among the best is classified as 1+, whilst one which is not quite so seriously affected by the test as the mental standard adopted for class 2 would be graded as 2−. In any such classification as this the personal factor is necessarily very large; nevertheless, it is found that practised observers agree very closely in their grading of any particular glass.

Only a few attempts have been made as yet to examine the chemical nature of the corrosion products on the surface of the glass resulting from the "dimming" test. In many cases they are not soluble in water, and where the corrosion is marked the surface of the glass cannot be restored by cleaning. In the case of some lead glasses, soluble lead compounds have been identified on the attacked surface, and in others alkali carbonates have been detected. Further work is needed on this point.

It should here be stated that since the "dimming" test described in this paper was elaborated, Mr. Twyman, of Messrs. Hilger, Ltd., has kindly directed the attention of the authors to a paper by Zschimmer,* in which that author describes in detail the apparatus used by him. As there appears to be no means of accurately controlling either the temperature or the moisture content of air, it is somewhat surprising, in the light of the experience of the present authors, that Zschimmer found the test of much practical value.

Some Typical Results.

In table I will be found the percentage composition of eleven glasses, together with a column indicating their reputation from actual experience in optical instruments. It should be stated that SO_3 was present in traces in many of these glasses, but was only determined in *A*, where the quantity was considerable. The column headed H_2O refers to combined water resulting from slight hydration of the glass powder during grinding. This moisture will vary with one and the same glass powder, according to its degree of fineness, the humidity of the air during grinding, and

---

* *Deut. Mekaniker-Zeitung*, 1903, **7**, 53.

TABLE I.

Ref.	Glass. Chemical type.	SiO_2	B_2O_3	CaO	BaO	PbO	ZnO	Sb_2O_4	Al_2O_3	MgO	Na_2O	K_2O	SO_3	H_2O	Reputation, etc.
A	Lime-soda-potash silicate...........	73·03	—	6·91	—	—	—	—	0·74	0·53	12·24	4·38	1·35	—	Very poor.
B	Lime-soda-silicate	74·63	—	6·95	—	0·07	0·39	0·37	3·19	0·11	14·51	—	—	—	Very poor.
C	,, ,, ,,	73·83	—	7·08	—	—	—	—	1·73	0·15	16·59	0·21	—	—	Very poor.
D	Lime-soda-potash silicate...........	73·82	—	7·16	—	0·12	—	0·30	1·43	0·27	13·21	3·77	—	—	Very poor.
E	Lime-soda-potash silicate...........	71·31	—	10·08	—	—	—	—	1·39	0·23	6·70	10·31	—	0·17	Fair.
F	Lime-soda-silicate	71·70	—	11·41	—	—	—	0·33	1·92	0·29	13·64	0·99	—	—	Fair.
G	Baryta-soda-silicate	67·02	—	0·86	9·88	—	2·01	—	0·70	0·35	17·35	1·40	—	—	Very poor.
H	Lead-soda-potash silicate...........	65·24	—	0·57	—	12·00	2·16	—	1·45	0·36	13·53	4·53	—	—	Very poor.
I	Baryta-soda-boro-silicate...........	68·22	10·11	0·60	3·19	—	—	—	1·33	0·32	13·34	2·89	—	—	Good.
J	Lead potash silicate	43·09	—	—	—	43·52	—	0·10	0·80	—	2·22	9·89	—	0·22	Doubtful.
K	Barium-lead-zinc-potash silicate	56·65	—	—	14·75	10·28	4·01	—	0·38	—	2·04	11·93	—	—	Good.

time of exposure. In certain circumstances this hydration might be sufficient to affect the other analytical results, but for the immediate purpose of this work was not regarded as of sufficient importance to require determination in every case. It was therefore determined in two cases only, glasses *E* and *J*, where, owing to the circumstances in which the samples were powdered, it was suspected that the quantity might be considerable.

Table II. gives the results of the "dimming" test (thirty hours at 80°) and of the iodoeosin tests on the glasses in table I.

It will be observed that in all the examples in these tables there is undoubtedly a relation between the behaviour of the glass in the "dimming" test, the "weathered" iodoeosin value, and the reputation of the glass. This will be evident from a comparison of *E*, *F*, *I*, and *K* with the other glasses.

The number of glasses in these tables is too limited to enable any general conclusions to be drawn, but it is interesting to note that in the case of the lime-alkali-silicates, the durability appears to depend largely upon the proportion of lime. This will be seen by comparing glasses *B* and *F*, both essentially lime-soda-silicates, and becomes more evident if the *molecular* percentage composition is calculated:—

Composition in Molecules Per Cent.

	SiO_2	CaO	ZnO	Al_2O_3	MgO	Na_2O	K_2O
B ...	75·7	7·5	0·3	1·9	0·2	14·2	—
F ...	72·2	12·3	—	1·1	0·4	13·3	0·6

The molecular proportion of alkali is practically the same in each case. It is probable that the superior behaviour of *E* as compared with *D* (both of which contain potash as well as soda) is mainly to be attributed to the difference in lime content, although the lower proportion of alkalis in *E* may be partly responsible for its better behaviour. The molecular percentage composition of these glasses is:—

Composition in Molecules Per Cent.

	SiO_2	CaO	Al_2O_3	MgO	Na_2O	K_2O
D	75·3	7·8	0·8	0·4	13·0	2·5
E	74·0	11·2	0·8	0·4	6·7	6·9

With regard to the other glasses in tables I and II, samples *G*, *H*, and *I* are specimens of Jena optical glass classified in Schott's catalogue by the "weathered" iodoeosin value as of durability h3, h5, and h1 respectively. The small proportion of bases other than alkalies in sample *I* is remarkable, and the satisfactory behaviour of this glass is probably due to the presence of boric acid. It would have been interesting to investigate this glass further, but no more of the sample is at present available.

TABLE II.

Results of "Dimming" Test (Thirty Hours at 80°) *and Iodoeosin Values of Glasses in Table I.*

	Appearance of polished surface at conclusion of "dimming" test.					Iodoeosin value, mg. per 100 sq. cm.	
	To unaided eye.						
		After removal from tube D.					
Glass.	In tube D.	Dew disappeared in	Surface after disappearance of dew.	Under microscope 2/3 in. objective.	Classification by dimming test.	On freshly broken surface.	On broken surface after "weathering" for 7 days at 18°.
A	"Dewed"	30 min.	Uniformly "filmed."	Uniform very finely granulated appearance. together with definite drops of liquid irregularly distributed over the surface.	3	0·30	2·21
B	,,	15 ,,	Distinctly "filmed" more marked at one end of plate.	Very finely granulated surface, especially marked at one end of plate. One area of well-defined drops of liquid.	3	0·39	0·60
C	,,	1 hour	Heavily "filmed" no longer transparent.	Covered with deposit of crystalline appearance, many fern-like clusters, and irregular accumulations of smaller crystalline particles with nuclei of larger ones.	3	0·39	0·37
D	,,	20 min.	Distinctly "filmed"	Strongly corroded areas of granular appearance, fern-like clusters, and numerous drops of liquid.	2+	0·16	0·25
E	,,	10 ,,	Slightly "filmed"	Slightly granulated over whole surface. Some definite drops of liquid.	1+	0·13	0·11
F	,,	5 ,,	Little affected.	A few finely granulated areas, and clusters of minute drops of liquid.	1+	0·13	0·14

TABLE II. (*continued*).

Glass.	Appearance of polished surface at conclusion of "dimming" test.				Classification by dimming test.	Iodoeosin value, mg. per 100 sq. cm.	
	Tounaided eye.						
		After removal from tube D.					
	In tube D.	Dew disappeared in	Surface after disappearance of dew.	Under microscope 2/3 in. objective.		On freshly broken surface.	On broken surface after "weathering" for 7 days at 18°.
G	"Dewed"	3 min.	Decidedly corroded, no longer transparent.	Strongly corroded, surface had marked crystalline appearance, numerous fern-like clusters, no drops of liquid.	3	0·21	0·31
H	,,	1 ,,	Decidedly "filmed."	Whole surface slightly granulated, many lines of marked corrosion, and concentric areas of crystalline appearance.	2+	0·66	0·97
I	No dew.		Very slight "film" over about one quarter of area.	The slightly filmed portion of surface showed a few slightly granulated areas. No drops of liquid. Rest of surface unaffected.	1	0·02	0·04
J	,,		Uniformly "filmed."	Uniform very finely granulated appearance, small drops of liquid in lines and clusters.	2	0·35	0·36
K	,,		Small! "filmed" areas, mainly unaffected.	The filmed areas showed a finely granulated appearance, rest of surface unaffected.	1+	0·13	0·13

TABLE III.

Results of "Dimming" Test (Thirty Hours at 80°) and Iodoeosin Values of Various Glasses.

	Appearance of polished surface at conclusion of "dimming" test.					Iodoeosin value, mg. per 100 sq. cm.	
	To unaided eye.						
		After removal from tube D.					
Glass.	In tube D.	Dew disappeared in	Surface after disappearance of dew.	Under microscope 2/3 in. objective.	Classification by "dimming" test.	On freshly broken surface.	On broken surface after "weathering for 7 days at" 18°.
Plate	No dew		Distinctly "filmed"	Numerous corroded areas with finely granulated appearance. Clusters and lines of drops of liquid. Corrosion very marked in places.	3	0·13	0·27
H.C.	Dewed	2 min.	Slightly "filmed"	Very finely granulated appearance. Lines of small drops of liquid. Some larger drops containing solid matter in suspension.	2	0·25	0·26
Spectacle *C.*	"	"	Distinctly "filmed"	Very finely granulated appearance, especially marked in certain areas. Numerous parallel lines of drops of liquid. Whole surface affected.	2+	0·29	0·43
Soft *C.*	"	15 "	Distinctly "filmed"	Dense clusters of large drops of liquid over whole surface. Some scattered accumulations of solid particles.	3	0·14	0·51
M.B.C.	No dew		No perceptible "film"	A few isolated solid particles of crystalline appearance, otherwise surface unaffected.	1	0·14	0·06
B.S.C.	Very slight dew	at once	Distinctly and uniformly "filmed."	Surface appeared to be covered with large particles of crystalline outline. Some clusters of drops of liquid.	2+	0·12	0·35

TABLE III. (*continued*).

	Appearance of polished surface at conclusion of "dimming" test.					Iodoeosin value, mg. per 100 sq. cm.	
	To unaided eye.						
		After removal from tube D					
Glass.	In tube D.	Dew disappeared in	Surface after disappearance of dew.	Under microscope 2/3 in. objective.	Classification by dimming test.	On freshly broken surface.	On broken surface after "weathering" for 7 days at 18°.
B.S.C.	Dewed	10 min	Slightly and uniformly "filmed"	Surface appeared to be covered with clusters of small particles of crystalline outline, between them were clusters of small drops of liquid.	2−	0·24	0·24
B.S.C.	No dew		Slightly "filmed" over ½ surface	The filmed half of the surface was covered with approximately circular areas of minute drops of liquid, with lines and annuli of similar drops between them.	2	0·09	0·06
B.L.F.	Dewed	1–2 min.	Distinctly "filmed"	Surface appeared to be covered with isolated particles of crystalline outline, in one area a dense accumulation of similar particles. Some large drops of liquid, and lines of smaller drops.	2+	0·17	0·59
B.L.F.	No dew		Very slightly "filmed"	Surface appeared covered with small scattered particles, probably solid. No drops of liquid.	1+	0·11	0·12
B.L.F.	Dewed	1–2 min.	Distinctly "filmed"	Very finely granulated, and considerable number of etched lines, some of which contained minute drops of liquid. Some larger drops also present.	2	0·14	0·27

TABLE III. (*continued*).

Glass.	Appearance of polished surface at conclusion of "dimming" test.				Classification by dimming test.	Iodoeosin value, mg. per 100 sq. cm.	
	To unaided eye.						
		After removal from tube D.					
	In tube D.	Dew disappeared in	Surface after disappearance of dew.	Under microscope 2/3 in. objective.		On freshly broken surface.	On broken surface after "weathering" for 7 days at 18°.
L.F.	No dew		Very slightly "filmed"	Very finely granulated, but only to a slight degree.	1+	0·41	0·16
L.F.	Dewed	15 min.	Distinctly "filmed"	Marked corroded areas of granular appearance. Lines of apparently solid particles. One irregular cluster of drops.	2+	0·11	0·12
H.F.	No dew		Distinctly "filmed"	Surface appeared to be covered with small particles of crystalline outline. Drops of liquid in lines, clusters, and irregularly scattered.	2	0·35	0·36
H.F.	No dew		No appreciable "film"	A few scattered solid particles of crystalline outline.	1	0·11	0·12
H.F.	Dewed	1–2 min.	Slightly "filmed"	Numerous isolated particles of crystalline outline and varying size, many of them surrounded by minute drops of liquid. Short lines of drops and circular corroded areas.	2	0·43	0·11
E.D.F.	Dewed	1–2 min.	Scarcely perceptible "film"	A few isolated solid particles, in some areas in lines. No drops of liquid.	1+	0·15	0·11

Table III gives the results of the "dimming" and iodoeosin tests on seventeen different glasses, the composition of which has not yet been determined. It has been included here to demonstrate that durability is dependent upon other factors than mere qualitative composition. There has been too great a tendency to approve or condemn a glass from experience of one example of a type. The result is that different glasses are recommended for the same purpose, and confusion arises. Table III shows clearly that different glasses of the same qualitative composition differ very materially in their behaviour under our tests. This will be seen by comparing the three samples of Baryta Light Flint (B.L.F.), the two Light Flints (L.F.), and the three Heavy Flints (H.F.). Further investigation will probably show these differences to be due, in part at least, to differences in composition.

As the series of glasses in table III covered a fairly wide range of different types, it was thought of interest to calculate the correlation coefficient between the "weathered" iodoeosin value and the behaviour under the "dimming" test, assigning the value of $1\frac{1}{3}$ to a 1+ glass and $1\frac{2}{3}$ to a 2− glass, and so on. The correlation coefficient calculated on this basis is 0·67, which indicates a very fair degree of correlation between the two tests.

Conclusion.

It is claimed that the "dimming" test described above gives valuable information in a comparatively short time as to the durability of glass towards atmospheric attack. It is proposed to continue this work and to attempt to establish a relation between the chemical composition of a glass and its durability. The "dimming" tests described above have been carried out at 80°, but a number of experiments indicate that a lower temperature, or a shorter time of test, may enable sharper discrimination to be drawn between different glasses.

The authors desire to express their thanks to Mr. A. H. Collinson, C.B.E., Controller of Munitions Inspection, for permission to publish these results; to Mr. G. H. Perry, M.B.E., Director of Chemical Inspection; and Lt.-Col. A. C. Williams, C.B.E., R.A., for the interest they have taken in the investigation, and to Mr. H. K. Frew for valuable assistance in carrying out the experiments.

Directorate of Chemical Inspection,
Royal Arsenal,
Woolwich, S.E. 18.

VII.—*Some Experiments with a Gas-fired Pot Furnace.*

By Morris W. Travers, D.Sc., F.R.S.

(*Read at the Sheffield meeting, June 18th*, 1919.)

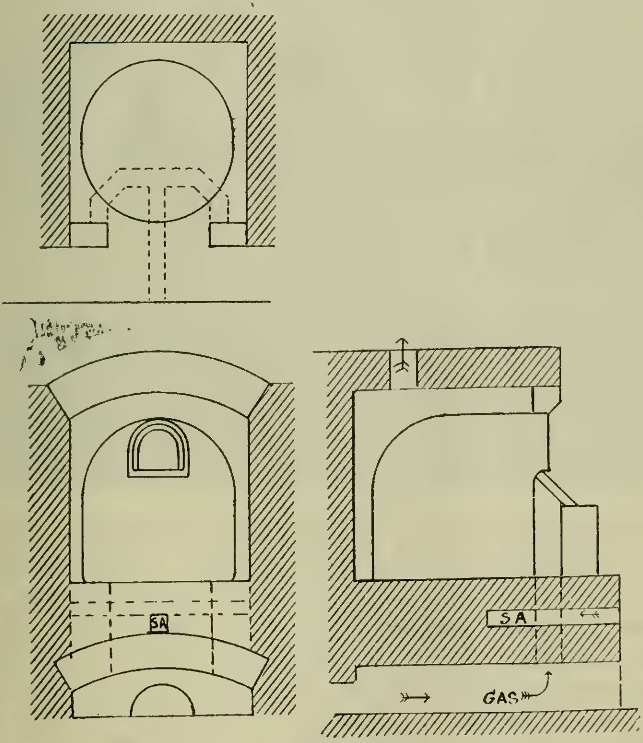
The immediate interest of these experiments lies in the fact that they throw some light upon an important cause of pot failure. It is also possible that the results may find application in the design of furnaces for special purposes.

In May, 1915, in order to meet the urgent demand for scientific glassware, it was necessary to erect, with the least possible delay, a furnace capable of founding resistance glasses, with an output of about five tons of glass per week. A furnace of a somewhat unusual type was selected, which was, I believe, originally designed by Messrs. Kempton, of Vauxhall, and was based upon the principle employed in a well-known type of horizontal gas-fired retort setting. The retort setting is figured in several works on general applied chemistry and requires but brief description. Covered pots, 36 in. by 38 in., were set in separate arches, arranged in pairs on either side of the gas producer. Gas entered each arch through a 14 in. semi-circular channel, running from the back to the front of the arch at two feet below the siege level. The gas, as it issued from the *nostrils* in the top of the channel, met the secondary air, and burned in the space below the siege, the products of combustion passing upwards through three ports on either side of pot into the arch.

The only advantage which the furnace presented was that pots were enclosed in separate arches, which could be isolated, by blocking the gas channel and flue, without putting out the whole furnace. The arrangement for heating the pots was, however, faulty, and the idea that the more rapid melting of the glass could be effected by heating the pots from below was entirely erroneous.

After the furnace had been at work some time the settings in all four arches were reconstructed. The gas now entered each arch through a central channel and passed up three ports on either side of the arch. The secondary air was brought through channels beneath the siege to meet the gas about eight inches below the siege level. Combustion took place at six points around the pot, practically in the arch itself. This arrangement gave as good results as can be expected from a non-recuperative furnace. It was with the furnace as now arranged that the experiments on glass pots described in this Journal * were carried out.

In the paper referred to it was pointed out that while the failure of the pots on account of the corrosion of the material by the glass could be prevented by firing the pots to a high temperature, and for about two days, before filling them with glass for the first time, this treatment did not materially reduce the tendency of the pots to crack down the front. The cracking of the pots down the front was attributed to the fact that, as the products of combustion do not pass over the front of the pot, the loss of heat by the walls of the pot, after filling, is not compensated for, so that at this point the pot material may fall below the critical temperature at which cracking takes place. It was obvious that if this explanation of the cracking of the pots was correct, it would be possible to prevent it by burning the gas as near the front of the pot as possible. With this object in view, in reconstructing the furnace, the following



SA = *Secondary air.*

---

* Trans., 1918, 2, 170.

arrangement, the details of which are indicated in the figure, was adopted.

The gas from the producer entered the arched space under the siege in each arch and ascended into the arch through two ports, 6 in. by 9 in., situated in front of the pot. The secondary air, which was not recuperatively heated, passed through channels indicated by the dotted line in the plan of the arch, and met the gas about eight inches below the top of the siege. By this arrangement the gas was made to burn in front of the pot, and the waste products escaped through a flue in the top of the arch. It would have been advantageous to place the flue low down in the back of the arch, but it was impossible to do this without pulling down the furnace.

The result of this experiment was as had been anticipated. The furnace was used for the manufacture of glasses which are by no means easy to found and plain, and the pots were worked out regularly three times a week. A very high quality of glass was obtained, and the cracking of the fronts was practically eliminated.

Beacon Hall,
Priory Gardens,
Highgate, London, N. 6.

VIII.—*The Exploitation of Glass-sands in the United States of America.*

By Professor P. G. H. Boswell, D.Sc.

(*Read at the Sheffield Meeting, February* 19*th*, 1919.)

In the Transactions of the Society of Glass Technology for 1917 (p. 147) the author gave a brief description, with analyses, of specimens of the six chief American glass-sands. For these samples he was indebted to Dr. G. Otis Smith, Director of the Geological Survey of the United States. The sands, which were collected by Mr. Ralph W. Stone, came from the following localities:—Ottawa, Ill. (The Ottawa Silica Company and the Wedron Silica Company); Cheshire, Mass. (The Berkshire Glass-Sand Company); Berkeley Springs, W. Va. (Berkeley Glass-Sand Company); Mapleton, Pa. (The Juniata White Sand Company, Baltimore); and St. Louis (The Tavern Rock Silica Company). Since the brief examination of these sands in the laboratory, the author has been able to visit most of the localities and confer with representatives of the companies.

72'

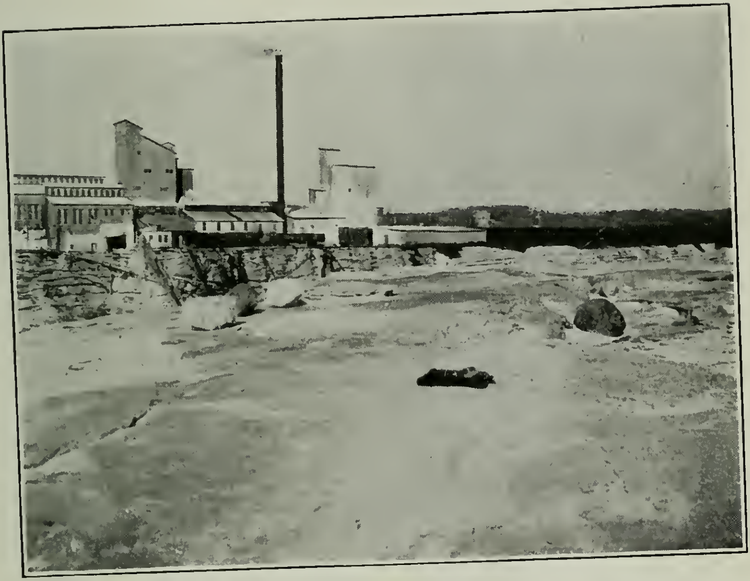


Fig. 1.—The Ottawa Silica Company's Works and Sand-quarry at Ottawa, Illinois.

[*To face p.* 72.

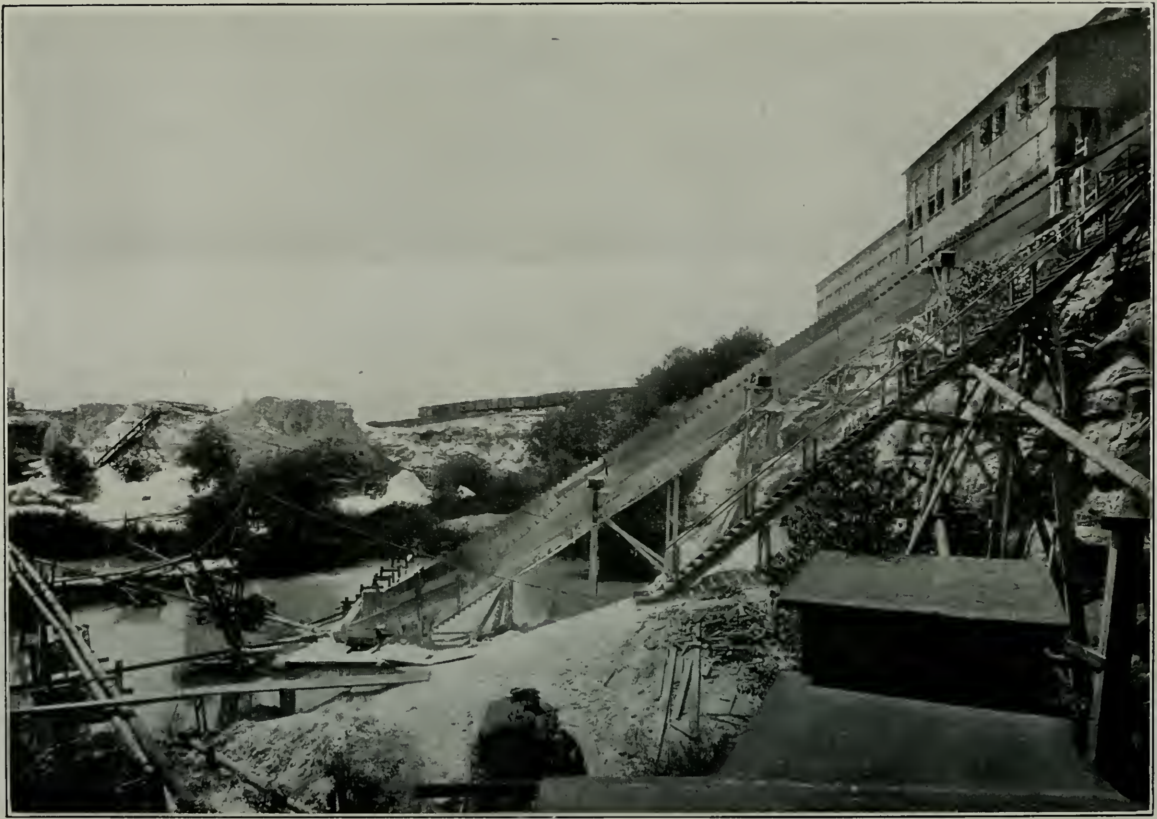


Fig. 2.—Ottawa Silica Company: Sand quarry and Elevator-belt.

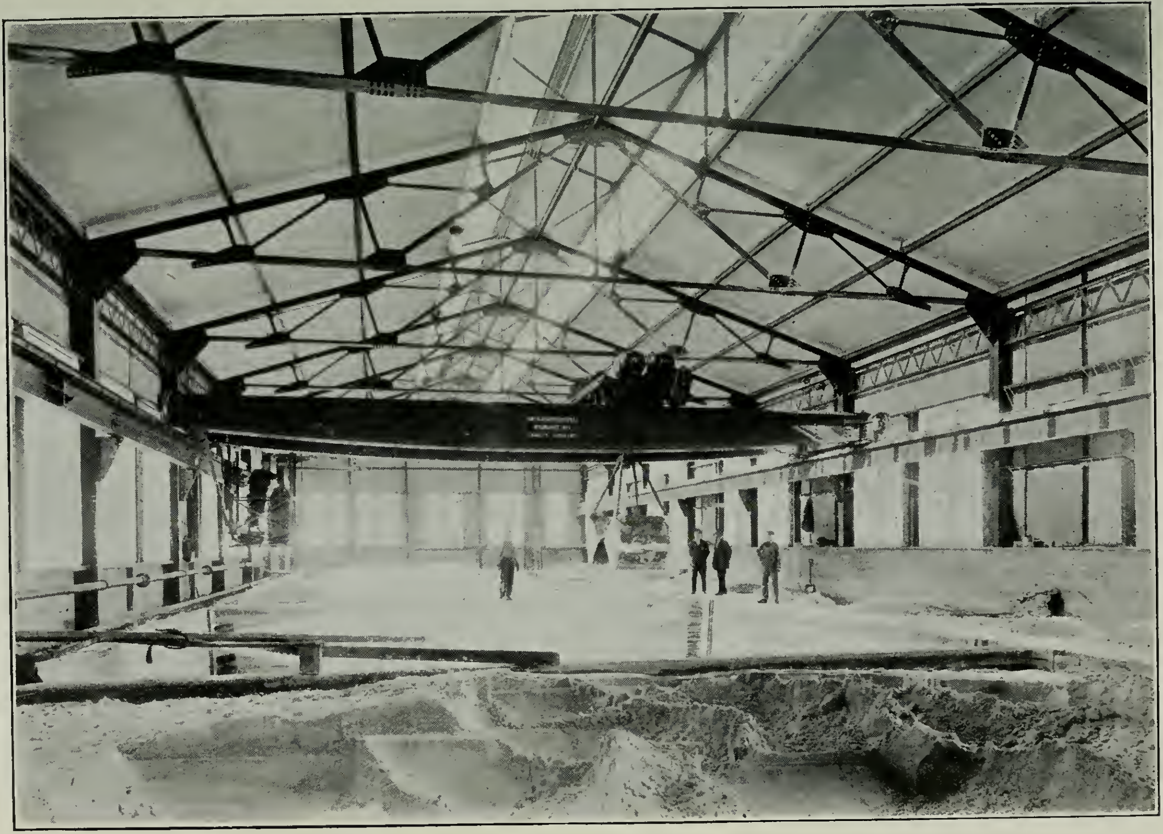


Fig. 3.—Ottawa Silica Company: The Sand-drying Plant.

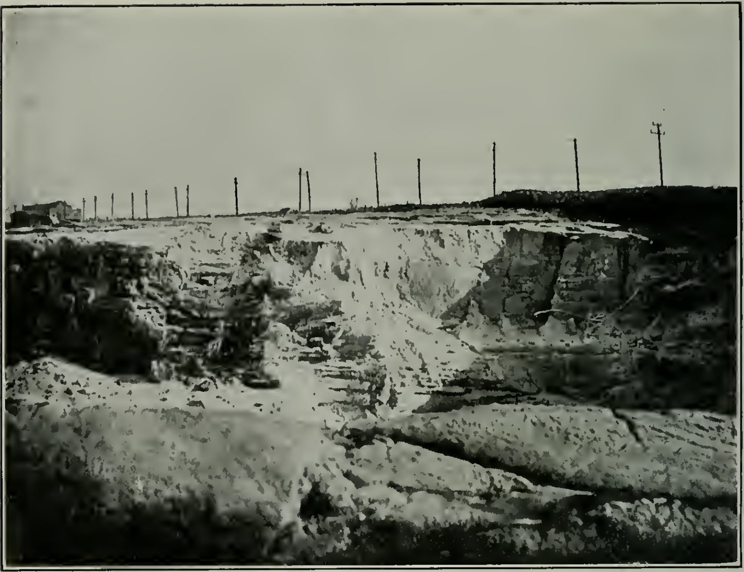


Fig. 4.—The Rockwood Silica Company's Sand-quarry at Rockwood, Michigan.

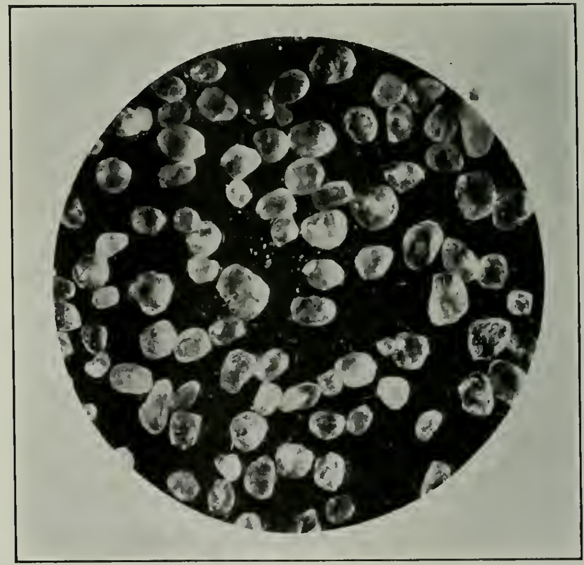


Fig. 5.—Photomicrograph by reflected light of glass-sand from Rockwood, Mich. (Rockwood Silica Company); magnified 17 diameters.

[*To face p.* 72.

The following notes, dealing with the actual working of two deposits (one of which has come into prominence within the last two years) may be of interest to both sand merchants and glass manufacturers in this country.

Ottawa, Illinois.

The St. Peter's Sandstone, of Carboniferous age, is worked extensively over the area around Ottawa, Ill., by various companies, including the Ottawa Silica Company, the Wedron Silica Company, and the United States Silica Company. The best of the sand (from the point of view of iron-content) is retained for glass-making, a large quantity goes to the steel works, and certain amounts of "Standard" sand and silica flour are produced.

Quarrying is comparatively easy, owing to the cropping out of the sandstone over a wide area. The beds are almost horizontal, and the overburden consists of only a foot or two of soil or peat. The surface of the sandstone has, fortunately, been scoured clean and gently rounded by glacial action; glacier-kettles (pot-holes) are seen here and there, sometimes containing rounded and faceted boulders, and large erratics are strewn over the surface (see Fig. 1). These boulders, foreign to the district and brought by the ice, are left on the surface, and, as the rock is worked, slowly find their way to the bottom of the pit. Although the sandstone as a whole is remarkably pure, the peaty covering has in places doubtless ensured its freedom from traces of iron-oxide pan which might have been left by surface waters. Here and there a little pan may be seen; ferruginous nodules occur occasionally, although on the surface only.

The following account relates to the largest workings, namely, those of the Ottawa Silica Company.

The quarries take the form of more or less circular hollows several hundred yards across and about forty feet deep. The excavations extend over a large district, the total area owned by the company being 400 acres. The quarries represent thirty or forty years' excavation, the present plant elevating 400 tons a day in the quarry photographed (Figs. 1 and 2). The total output is now 427,000 tons a year. Some seams of the rock are not quite so white as others, but all are mixed before being washed. The rock, which is a soft sandstone composed of rounded grains of quartz, is usually almost entirely disintegrated in the course of blasting, and subsequent immersion in water is sufficient to cause it all to fall apart as free sand. The material is sluiced down, after being blasted, and piped to the foot of the elevator (see Fig. 2). The elevator consists of the usual form of belt, but has wooden "riffles" about 4 inches high and 12 inches apart, extending across its whole width. The riffles consist of two battens, the upper one screwed on to the lower. As they wear, therefore, the upper ones are replaced without interfering with the fixing of the lower to the belt. This simple form of elevator is found to be most effective. As already stated, it raises 400 tons a day, and there is no danger of contamination of the sand by iron.

After elevation, the sand is screened, and is washed by being run down in water currents into successively lower and lower shallow tanks made of concrete. Thence it is delivered into draining bins (see Fig. 3), and is afterwards passed down through a series of dryers consisting of horizontal steam-coils. The upper pipes are 1¼ inches in diameter, with a clearance of 3 to 5 inches. The clearance is reduced in the lower coils until, at the bottom, the pipes have interspaces of 1 inch between them, and are 1 inch in diameter. By the time the sand has worked through to the bottom it is perfectly dry. It is then stored in concrete bins and delivered as required into covered wagons of 50 to 80 tons capacity.

The water from the washing-plant is run into large settling-ponds, where the aluminous and ferruginous slime separates out. No market exists at present for this material, which has the following chemical composition *:—

	Per cent.
SiO_2	87·21
Al_2O_3	7·50
Fe_2O_3	0·52
MgO	None
CaO	None
Na_2O K_2O	0·20
Total	95·43

Remainder mainly water.

The above analysis indicates that, besides clayey and ferruginous matter, much fine silica had also been removed from the sand.

The sand itself has the following chemical composition:—

	(1). Per cent.	(2). Per cent.
SiO_2	99·48	98·47
Al_2O_3	0·16	0·75
Fe_2O_3	0·02	0·08
MgO	0·05	0·08
CaO	0·11	0·21
Na_2O	None	None
K_2O	None	0·06
TiO_2	n. d.	0·05
Loss on ignition	0·13	0·47
Totals	99·95	100·17

1. Washed sand for glass-manufacture. 2. Unwashed sand for steel-furnace and foundry purposes.

---

* *U.S.G.S. Bull.* 285, p. 461.

"Silica flour" is prepared by grinding the sand to a powder in ball-mills. The balls consist of Danish flint pebbles 2 to 3 inches in diameter, and the cylinders are lined with Belgian quartzite. The ground product is air-separated and passes a 180-mesh sieve. Considering the fine grinding which goes on, the works, which are well ventilated, are remarkably free from dust.

The sand itself is screened for various purposes. Ottawa sand which passes a screen having 20 meshes to the linear inch, and is retained on one having 30 meshes to the linear inch, is known as "Standard Sand" on account of its being the sand specified for cement testing, road-metal abrasion, etc. The sands supplied for glass-making are rather finer in grain, as the following percentage mechanical composition shows:—

>1 mm., 0·5; $>0{\cdot}5$ and <1 mm., 21·6; $>0{\cdot}25$ and $<0{\cdot}5$, 75·6; $>0{\cdot}1$ and $<0{\cdot}25$, 1·3; $>0{\cdot}01$ and $<0{\cdot}1$, 0·3; $<0{\cdot}01$, 0·7.

Total sand-grade, $>0{\cdot}1$ mm., 99·0.

$$\left[\frac{VCS}{0\cdot5},\ \frac{CS}{21\cdot6},\ \frac{MS}{75\cdot6},\ \frac{FS}{1\cdot3},\ \frac{s}{0\cdot3},\ \frac{c}{0\cdot7};\ \frac{S}{99\cdot0}.\right]$$

The heavy detrital minerals are small in quantity (0·02 per cent.) and of little interest. Many are well rounded, blue and brown *tourmaline*, *zircon*, and large *garnets* (0·2 mm. diameter) being notable. *Pyrite* with excellent crystal form is abundant, and is undoubtedly authigenous, that is, has been produced since the deposition of the sandstone; it has suffered no abrasion. Its presence probably accounts for the 0·02 per cent. of Fe_2O_3 indicated in the analysis, an amount larger than the appearance of the sand would lead one to expect.*

The price of the screened, washed, and dried sand is $2.25 (=about 9*s*. 4*d*.) a short ton (2000 lb.). The quarrymen are paid 35 cents per hour, the overman receiving 50 cents. The workmen's hours are from 6.30 to 11.30 a.m., and from 12.30 to 5.0 p.m., but there is no restriction of output, and the men even stay late at night in order to keep the bins full. Drying is estimated to cost 20 cents per ton. Other firms considered that each process, such as washing, drying, etc., costs 30 cents a ton.

A few freights to the chief glass and steel making areas, together with the distances from Ottawa, may be instructive to British readers. The lowness of the freight commands attention, and it should be recollected that the sand is transported *dry* and in covered box-wagons.

---

* These mechanical and mineral analyses have already been published in the Transactions, I. (1917), p. 149, but are repeated here for convenience.

City and State.	Distance from Ottawa.	Rate from Ottawa.
Pittsburgh, Pennsylvania	554 miles	$3·20 per ton.
Columbus, Ohio	400 ,,	2·50
Cincinnati, Ohio	384 ,,	2·30
Toledo, Ohio	329 ,,	2·30
Detroit, Michigan	357 ,,	2·30
Indianapolis, Indiana	268 ,,	1·90
Chicago, Illinois	85 ,,	0·90
Milwaukee, Wisconsin	170 ,,	1·30
St. Louis, Missouri	259 ,,	1·30
Seattle, Washington	2,703 ,,	10·20
San Francisco, California	2,468 ,,	10·20

Rockwood, Michigan.

Within the last eighteen months, considerable quantities of an exceedingly pure sand have been worked at Rockwood, near Detroit, Mich., by the Rockwood Silica Company. In 1918 the optical glass made in America was prepared exclusively from this sand. Large quantities were also used in general glass-making, and a small quantity was also consumed in steel manufacture for refractory purposes.

Deep excavations in the Sylvania Sandstone (Monroe formation), of Silurian age, have been made about midway between Detroit and Toledo (see Fig. 4). The rock consists of a soft, white sandstone with some of the joint-planes and faces dirt-stained with clayey matter washed down by percolating water from the overburden of glacial drift. The latter is about 6 feet thick, and consists of boulder clay containing erratics of *granite*, *gneiss*, *dolerite*, etc. The working face of sandstone is 40 to 50 feet high, and the rock is not bottomed. The best seam of sandstone occurs at the top. Dark-coloured and blackish patches are seen in places on the face. Concretionary masses of pale blue *celestine* occur here and there.

Drilling and blasting are utilised to bring down the face. The broken material is then trolleyed up to the top of the quarry (which is a more or less circular hole), where it is dumped upon a reserve heap. It is then crushed between light rolls and transported upon a belt-conveyor to the screens, where the sand passes on, but the uncrushed lumps of rock are side-tracked to additional pulverising plant consisting of manganese steel jaws and a pan (or chaser) mill. Fortunately, the sandstone is soft, and very little iron is therefore introduced from the machinery. The sand is next washed in large tanks, where it is kept for a time in a state of agitation by means of worm-screws. Thence it is elevated into bins and dried over steam-coils.

A chemical analysis of an average quartered sample mixed from several parts of the pit, and not washed, is as follows:—

	Per cent.
SiO_2	98·00
Al_2O_3	0·13
Fe_2O_3	0·012
TiO_2	Trace
MgO	0·41
CaO	0·70
SrO	0·02
K_2O	None
Na_2O	None
H_2O+	0·16
CO_2	0·73
Total	100·16

The percentages of lime, magnesia, and carbon dioxide point to the presence of *calcite* and *dolomite* (to the extent of nearly 2 per cent.). The presence of carbon dioxide in carefully washed specimens serves to show that the carbonates are present in a crystalline form and not as fine, chalky material.

The iron-content is very low; hence the use of the sand for optical glass. With the elimination of the rhombohedral carbonates, the proportion of silica would doubtless rise to more than 99 per cent. Much of the sand worked doubtless possesses a higher percentage of silica than that indicated by the above analysis.

The sand is fine-grained, and the grains are extraordinarily well rounded, especially when their fineness is taken into consideration (see Fig. 5). The grading is good, as the following percentage mechanical composition of a sample (which was not washed) indicates:—

$>0·5$ mm. and <1 mm., 2·2; $>0·25$ and $<0·5$, 79·5; $>0·1$ and $<0·25$, 18·0; $>0·01$ and $<0·1$, 0·2; $<0·01$, 0·1.

Total sand-grade, $>0·1$ mm., 99·7.

$$\left[\frac{CS}{2·2}, \frac{MS}{79·5}, \frac{FS}{18·0}, \frac{s}{0·2}, \frac{c}{0·1}; \frac{S}{99·7}.\right]$$

The fineness and evenness of grain doubtless explains the free and rapid fusing of glass-melts made from the sand. The glass produced is said to be very brilliant.

A mineral analysis reveals the presence of a crop of colourless crystals heavier than bromoform (density 2·8). Unlike the grains of quartz, these are irregular and angular in shape, often showing crystal outlines. From the high refractive index, birefringence (lower than quartz), and the crystal faces present (dome, basal plane, and prism), the mineral is identified with *celestine.* Small *zircon* crystals also occur.

In conclusion, the author desires to express his great appreciation of the reception accorded to him by the officials of both the Ottawa Silica Company and the Rockwood Silica Company, and of the kindnesses he received at their hands. To Dr. H. F. Harwood, of the Imperial College of Science and Technology, he is indebted for chemical analyses, and to Mr. G. S. Sweeting, also of the Imperial College, for taking the photomicrograph shown in Fig. 5.

DEPARTMENT OF GEOLOGY,
THE UNIVERSITY,
LIVERPOOL.

IX.—*The Preparation of Raw Materials for and the Manufacture of Glass-house Pots.*

By B. J. ALLEN.

(*Read at the Birmingham meeting, March* 19*th*, 1919.)

THE first point to consider in the provision of suitable refractory pots is the selection of the raw materials, and for guidance in this matter we must rely chiefly on scientific workers. All clays are good for something, but which are the best for glass house pots seems at the moment debatable. If we accept the provisional specification drawn up by the Refractories Committee, the questions arise of how many of the available clays meet these requirements and how unsatisfactory clays can be treated to make them suitable. I suggest that in most cases the treatment of a Grade 3 clay to produce Grade 1 presents no insurmountable difficulties. Deflocculation of the clay and precipitation of the coarse impurities will materially assist in this direction.

Some five or six years ago twenty-one fireclays from various parts of Great Britain, none of which would meet the specification of a Grade 1 clay, were deflocculated, and seventeen, after treatment, would pass the test as far as alumina content was concerned. In most cases it appears possible, therefore, for the owner of an inferior clay to raise the quality of his material to somewhere near the ideal clay.

In order to illustrate further the effect of deflocculation, a specimen was prepared from a low-grade Staffordshire saggar marl and then fired. Although only fired to 1200°, it sintered so as to become almost vitreous, the squatting temperature nevertheless being higher than cone 30. The untreated clay was not good enough for common saggars, and about 30 per cent. of impurities were removed to give the result stated.

The Deflocculation and Electrolytic Collection of Clay.

A brief description of the method of deflocculating clay and its electrolytic collection may be of interest.

For experimental and research purposes the apparatus necessary is both cheap and simple. Fig. 1 shows the apparatus which I have used for this purpose. It gives on the small scale all the results which can be obtained on a commercial machine.

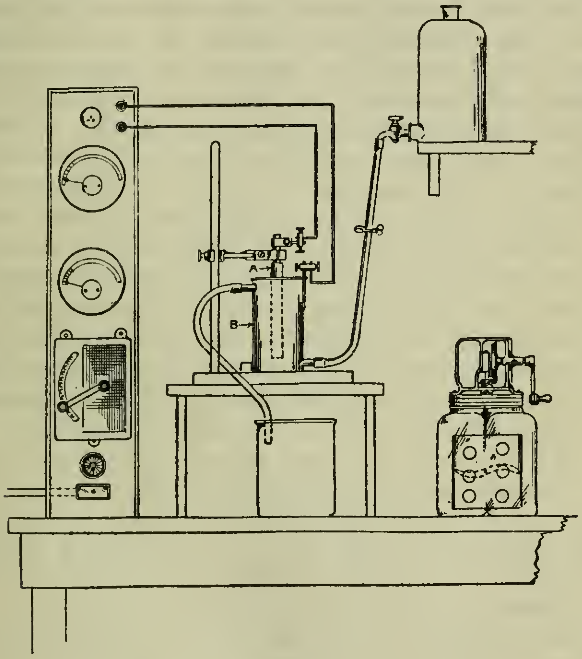


FIG. 1.

A is a type metal rod 9 inches long and ¾ inch in diameter. *B* is a copper can 6½ inches high and 3½ inches in diameter. The rod is supported about 1 inch from bottom of the can by a clamp attached to a wooden retort stand. The can is connected to the negative pole and the stick to the positive pole of an electric circuit.

In principle, the treatment of the clay material consists in grinding and then blunging 1 kilo. of clay with 2 kilos. of distilled water to which has been added 2—3 c.c. of a 10 per cent. solution of silicate of soda, sodium hydrate, or sodium carbonate.

The blunging should occupy one and a-half to two hours, the slip then run into a settling jar and allowed to remain for one to one and a-half hours, during which time the coarse impurities will subside. The suspension should then be syphoned into another jar and allowed to stand for two hours to allow the finer impurities to settle. After this period, the suspension is ready for the clay to be collected. For this purpose, the thin liquid is poured into the can and the current switched on at a pressure of between 55 and 85 volts. The most suitable pressure varies with each clay, but, generally speaking, the higher the voltage the dryer the clay when deposited. After about three minutes the current should be switched off and the adhering clay removed from the stick.

My reason for referring to this process is that I am convinced it is possible to avoid the necessity for a special "fusible bind clay" as referred to in the specification drawn up by the Glass Refractories Research Committee by making the base clay itself more plastic and more easily sintered. I think the grog should also be made from the same material, and thus provide a clay and grog mixture with the same ultimate composition throughout, and not likely to be attacked by the glass in one place more than another. The increased plasticity due to deflocculation permits a higher percentage of grog being used, thus reducing the drying and firing contraction, and to a great extent eliminating cracking.

If all the refractory clays used for making pots were treated in this way and the physical and chemical properties before and after treatment tabulated, the information would be of great value and the standardisation of materials would be simplified. The analysis of the residues or precipitates would also be useful to indicate possible sources of trouble when using the untreated clay.

I venture to suggest that the Refractories Committee should go further than specify the composition of the materials required. They should suggest the possible methods of treating a rejected clay to bring it up to the standard required. In this way the sympathy of the clay owner would be enlisted. Research in this direction is going on at Stoke, but the problems cover a wide field, and the special consideration of refractories for glass works should be the business of the Society of Glass Technology.

The Preparation of the Grog.

The grog should be prepared from the specified clay or clay mixture of the same composition as the base clay, and should be fired long enough and at a temperature sufficiently high to prevent any marked after-contraction. It has been said that "grog is the skeleton and clay the flesh." When grog is only fired to a temperature not exceeding that of the prepared clay, then the two will form a uniform structure at a comparatively low temperature. It is absolutely essential that the manufacturer should prepare his grog so that this interaction shall be delayed as long as possible. The harder the grog is fired and the more even the distribution, the more satisfactory the ultimate refractory material.

There is an important point with regard to hard-fired grog indicated by Dr. Mellor some years ago. Fireclays lose alkalies and alkaline earths on exposure to a high temperature, so that grog after a prolonged heating is more refractory and less fusible than ordinary fireclay grog. Dr. Mellor also showed that seven firings to 1200° of a North Staffordshire fireclay resulted in a loss of more than 20 per cent. of the alkalies.

Black-cored grog should never be used. This material is a fruitful source of blow-holes or fissures, and opens a way for the glass materials to attack the pot. Even in a finely ground condition there is a great risk of pin-holes. If the surface of the clay is engobed (and the skin face of fine clay is, to my mind, an engobe), blisters and blow-outs will occur.

The Grinding of the Grog.

The grinding of grog should be done on an edge runner mill with a perforated bottom and the rollers set half an inch from the grinding ring. The scrapers should be set to throw a good body of material under the rollers, with the object of crushing it to angular fragments rather than grind to spherical forms. If the rollers, scrapers, and rate of feeding are properly adjusted, the finest grog grains will be angular.

When a suitable clay is obtainable, calcining before grinding is an advantage. The shrinkage cracks which occur during firing make the piece almost ready to fall to pieces, and if fired to a high enough temperature it will be hard and brittle and easily crushed to produce those angular, sharp-cornered fragments which form ideal adhering surfaces for the binding clay.

If electromagnets are subsequently used to treat the ground grog, care should be exercised to prevent beards of iron particles dropping off the magnet when a drop in voltage occurs. There is more trouble from this source than most people imagine.

The Size of the Grog Employed.

The size of the grog is possibly one of the most debatable points in connection with a specification for glass pots. It is generally accepted that the greater the size and the higher the proportion of grog, the greater the resistance to sudden changes of temperature, but the less the binding power and crushing strength of the finished refractory material. This conclusion, however, is not correct in all cases. Much depends on the material used in making the grog, its treatment, the manner of mixing clay and grog, and the process employed in making the article.

It is possible to make a satisfactory refractory pot entirely of grog if a sufficient percentage is ground to colloidal dimensions and the necessary method of manufacture employed.

The Mixing of Clay and Grog.

Dealing now with the mixing of clay and grog, milling on an edge runner pan is, in my opinion, not a good way of getting a homogeneous mixture. In fact, the result obtained is very much dependent on the man turning the clay with a shovel. The milling in a pan also alters the size of grog by further crushing and grinding the particles to such an extent that the ultimate result cannot be predicted. Pugging is also inefficient for mixing, and often gives ball-like formations to the clay and with varying water contents.

The water-content of pugged clay can be regulated to some extent by passing an electric current through the mouthpiece and an insulated ring in contact with the clay, the mouth being connected to the negative pole.

To get a satisfactory mixture, I am convinced that "slipping" is the only way, and the cost is no more than when using pan and pug. If the water and alkali are carefully adjusted to the dry materials, a perfect mixture containing little if any more water than pugged clay can be obtained. The size of grog particle is not altered, and the bind clay is in an ideal condition for doing its work. There are a few precautions to be taken in mixing slip if the best results are to be obtained. The blunger should run at a fairly high speed, 80 r.p.m. being suitable for a blunger of 4 feet in diameter. The water, with alkali added, should be warm when put into the blunger, the clay then added, next fine grog, and lastly the coarse grog. The blunging should take about two hours. Some clays which are inclined to "gel" may require the addition of a barium salt, but this "gel" condition is an advantage rather than otherwise when a very big percentage of grog is used. The use of sulphite cellulose liquor as a substitute for silicate of soda is beneficial under some conditions.

This method of mixing clay and grog and making pots from the "slip" has distinct advantages over building pots by hand. In the latter process, the maker uses clay more or less homogeneous, and laboriously builds up a pot from small pieces of clay which he tries to combine into one homogeneous whole. Every time he runs his fingers or thumb across the clay he brings up a film of water and fine clay which does not take kindly to the next piece applied. To overcome this difficulty, he scratches and scores the clay with sufficient force to press the grog and clay of the piece being applied through the skin formed on the surface of the clay previously built up. This method of manufacture imposes limitations on the size of grog which can be used. If large grog is employed, the scratching and fingering are apt to displace the grog and leave air-pockets in the piece almost impossible to get rid of. This, I think, is the reason why fine grog is favoured by most makers. Having partly built the sides of a pot, the maker waits for the paste to stiffen somewhat before proceeding with the work, so that in the second stage of building a moister material is generally applied to the stiffened mass, and this process goes on until the pot is complete. The necessity for slow drying is undoubtedly due to the method of making, which introduces so many sources of weakness. Personally, I think it is a physical impossibility to stick two pieces of plastic clay together and leave no evidence of the fact. So it is no wonder the pot-maker considers he possesses wonderful ability. The mystery is that he is able to make pots suitable for the purpose required by the method employed.

In the process of "slip" mixing and casting, however, there are wide limits to the size of grog usable, and considerably more of it can be employed than is workable in pressing clay, so that the amount of bind clay need not be great. If much dust grog is used, the amount of bind clay can be reduced by 10 per cent.; or, as I have previously stated, if sufficient grog ground to colloidal dimensions is used, bind clay need not be employed at all.

Grog made from deflocculated clay and similar clay used for the bind will sinter at a much lower temperature than untreated clay. This is a great advantage in producing pots to be used at a low temperature, as the vitrification occurs so much sooner owing to the intimate contact of the fine particles. It is important to remember that the contraction is taken out of deflocculated clay gradually, beginning at a comparatively low temperature and continuing steadily to the melting point. In other words, the clay sinters at a lower temperature than untreated material, and the vitrification and contraction go on steadily until the squatting point is reached, a temperature invariably higher than is obtained with untreated clay.

The type of blunger for casting slip which appeals to me is constructed with a semicircular base and horizontal shaft. The usual form of flat-bottomed apparatus with vertical shaft has a tendency to cause the material to revolve in horizontal layers, and takes too long to give a proper mixing. The ordinary blunger will give satisfactory results if allowed time to do so.

Too short a period of blunging will frequently cause a "gel" formation to occur and, curiously, continuous blunging for too long a period will produce similar results with some clays.

The Casting of Pots by the Statical Process.

We will now consider the use of an ordinary plaster mould.

Fig. 2 shows a cored mould for casting an open top pot. The slip is poured through the funnels and a good head of slip provided. If the mould and slip mixture are in the right condition, a fairly good casting may be obtained from a mould of this class, but there are limitations. It is very difficult to get the core cast up, and it appears impossible to get the same density in the centre as at the faces. In one typical case which I have observed a crucible was cast hollow. This was the result of bad mixing of slip and defective work, but it clearly showed the

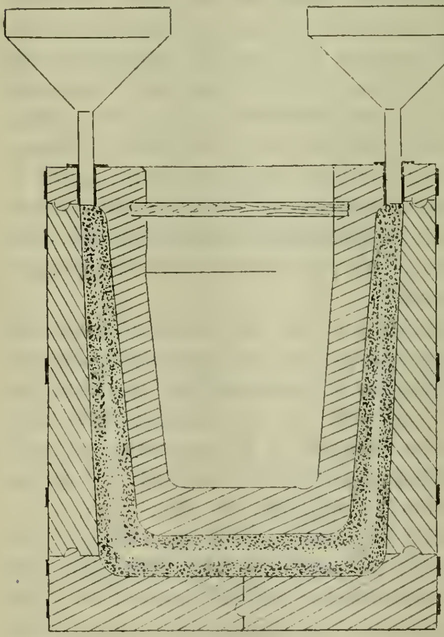


FIG. 2.

difficulties encountered in casting a thick piece. If the specimen had been cast solid, there would still remain a great difference in density between the centre and the sides, the consequences of which will be obvious. The defect can be obviated to some extent by first casting a core or liner, placing it in the mould, and casting round it. The core might be cast on a one-side mould and the skin of clay formed by contact with the plaster scraped off before placing in the mould. This would give a fairly satisfactory result, but it would not be homogeneous, and would have obvious indications of laminations.

Casting a covered pot in an ordinary plaster mould presents many difficulties. It is not possible to cast thicker than $\frac{7}{8}$ inch or 1 inch at the top of the mould before the clay begins to contract away from the plaster, and no further deposit is possible. Then when the superfluous slip is run out, the cast clay comes away from the top of the mould and the piece collapses. It may interest those who have had no experience of casting to know that a hot, excessively dry mould does not give the best results. This condition of the plaster gives rise to "filling marks," and causes the cast clay to come away from the mould sooner than it would otherwise do. For this reason, the experienced caster always sponges the face of a mould * taken from the drying shed.

The Vacuum Casting Process.

Having dealt briefly with some of the difficulties of manufacture by comparatively well-known methods, the next thing is to suggest how to eliminate these troubles.

Fig. 3 shows a mould with a case from which air, etc., may be removed by means of a vacuum pump. a, a indicate the half moulds of plaster,† d the case or jacket enclosing the mould, and c the wire netting used to reinforce the plaster. d^1 is the space which is connected to the vacuum pump by the connection e.

Fig. 4 shows a similar mould provided with a core.

The slip is run into the mould as shown at f. The air is exhausted from the jacket and a vacuum maintained until the desired thickness of deposit is obtained on the mould. The vacuum outside the mould causes the clay to remain in close contact with the plaster and also assists in removing the water from the slip. It will be obvious that so long as the clay is in contact with the plaster and the vacuum maintained, the thickness of deposit will continue to increase.

---

* The first casting from a new mould is generally a bad one.

† If a rim mould is used a, a can be in one piece.

If coarse grog is used, the interior of the cast pot will be left rough owing to projecting particles of grog, but this can be easily remedied by finishing the inside with knife and leather when the surface is fairly hard. Care must be exercised when doing this to press in the grog and not drag it into the holes. The first stage should be the exercise of pressure only. The alternative to this would be to fill the mould a second time with slip containing no coarse grog and to cast a fine surface layer.

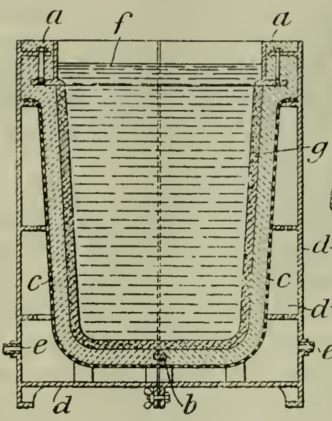


Fig. 3.

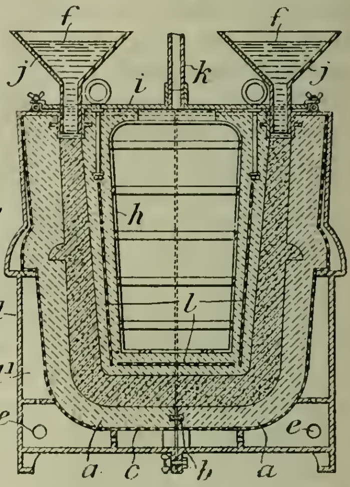


Fig. 4.

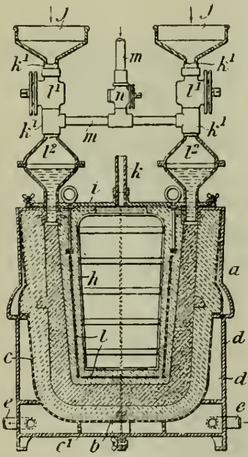


Fig. 7.

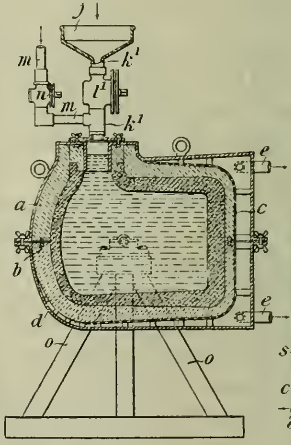


Fig. 6.

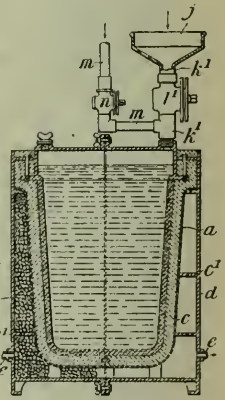


Fig. 5.

An abnormally thick pot or a quicker cast may be obtained by applying pressure to the slip in addition to the vacuum on the outside of the mould. The method of doing this is illustrated by Figs. 5 and 6.

Here the funnels are fitted with full bore stopcocks and reservoirs, through which the slip passes to the mould. There is also provision made below the stopcocks for connexion to an air compressor.

When the mould has been filled and working for a short time under vacuum, the stopcocks to the funnels are closed and compressed air is admitted to the slip. The application of pressure to the slip in a one-side mould is not so important as its application to a cored mould.

Fig. 7 shows the application of pressure to such an apparatus. If a pot with a very thick bottom and tapering sides is required, the top is liable to be cast dry and hard while the interior of the bottom and part of the sides are still in the slip stage, unless special precautions are taken. The problem is to get the slip supplied to the thick parts before the thin parts are hard. The application of pressure to the slip will do this.

The same principle is applied to the casting of a pot as is put into operation in a filter press. The pressure forces the clay slip through the thin parts and keeps a way open until the lower part is filled; then it gradually casts up solid to the top.

Casting a pot under these conditions gives a beautiful surface of fine clay all over the pot, which should be highly resistant to the attack of glass; but it is, I think, desirable to scrape off the skin on the outside of the pot before firing in order to expose a face of clay and grog which will withstand the temperature conditions better than the fine clay.

This type of mould is also very suitable for producing pots lined with special materials. The core mould can have a casting of fine material and then be placed in position, and the fireclay slip cast on it.

The Casting of a Covered Pot.

It is here I think that the vacuum process is indispensable if a perfect pot is to be produced.

Fig. 8 shows a mould for casting 38-inch dog-house pots. The mould is constructed in four parts, namely, base, two sides, and mouthpiece. It will be noticed that the vacuum space at the sides only extends a short distance. This arrangement is adopted in order to permit the base and sides near the bottom to be cast thicker than the top. There is one feature in the design of this pot I should like to alter and that is the mouthpiece. If this was made 14 inches or 15 inches wide, a man or boy could get inside and finish a pot without a second casting, thereby reducing the cost of manufacture. In the light of further experience, it may be necessary to cast the pot of somewhat porous material and then line with something more resistant to the attack of glass. If this happens to be a material which will run to a smooth face, then the alteration to the mould is unnecessary.

In an early paper on vacuum casting read before the Ceramic Society I recommended the tilting of the mould to empty out the superfluous slip. By exhausting the air from a closed tank mounted on wheels and sucking the slip from the mould into this tank the tilting is done away with. This method saves labour and is a cleaner and simpler way of removing what is not wanted.

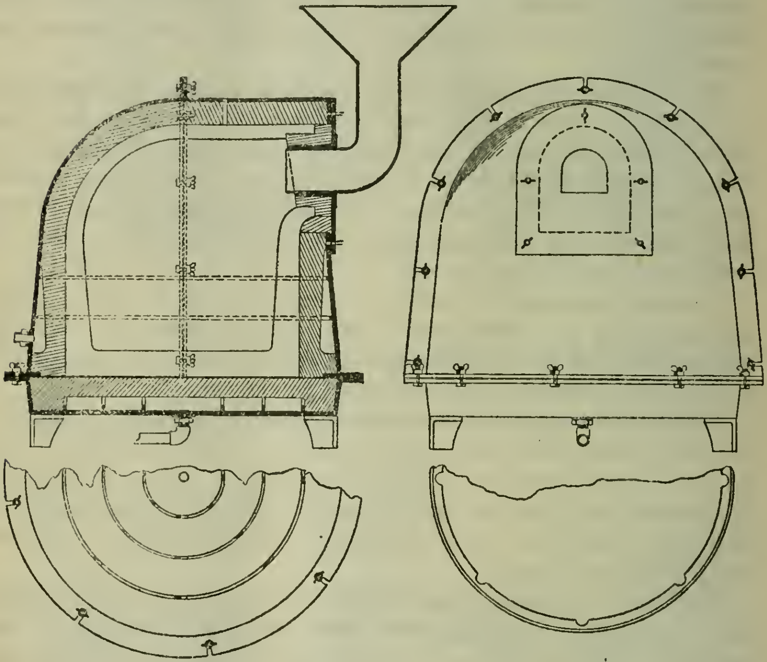


FIG. 8.

There is one other type of mould I wish to refer to. Fig. 9 shows how vacuum casting can be simplified, cheapened, and the vacuum casing made somewhat adaptable to various sizes of articles. The drawings show a "dandy pot" mould constructed with a framework of wood arranged to permit the mould sliding into the box like a drawer into a chest. The vacuum box shown is of wood and covered on the outside with zinc, the joint at the front being made with soft rubber tacked to the case. The arrangement permits a number of moulds to be fitted with one vacuum chamber, and the wood runners can be constructed to adjust the size of mould to the box. The wood framework also acts as a reinforcement and protects the plaster from injury. This method is applicable to large as well as to small moulds. A 38-inch pot can be dealt with in the same way, but in this case runner wheels would be fitted to the bottom of the mould to permit easy withdrawal. Obviously, a 38-inch pot mould casing could be used under these conditions for casting "dandy" pots.

Fig. 10 is a photograph of a section cut from the angle of a 38-inch dog-house pot, which was cast under a vacuum of 17 inches to 20 inches in the mould illustrated by Fig. 8. The pot was made from materials supplied by a pot-maker of repute, and fired in a muffle kiln to 1200° to 1250°. If a higher vacuum had been used the piece would have been denser.

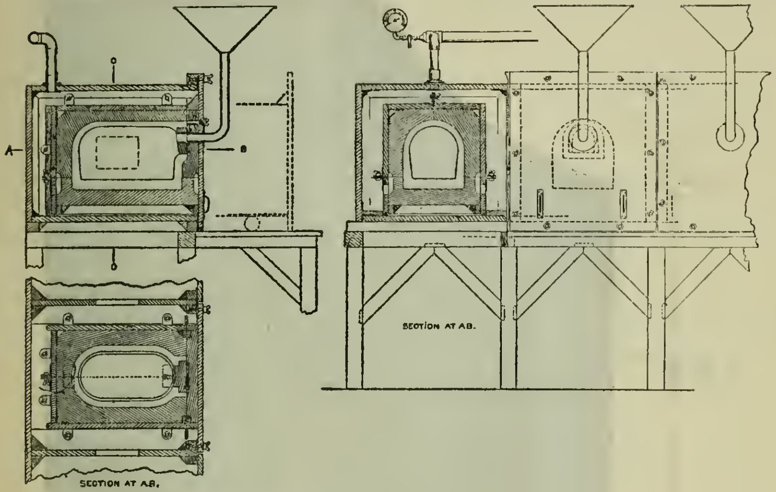


Fig. 9.

The grog was considerably bigger than that used by the pot-maker, and accounts to some extent for the porosity. The clay and grog provided were mixed in the proportions the pot-maker used and fired to 1250°, then crushed for use.

The block indicates how uniform is the mixture of clay and grog and the big percentage of grog which can be carried in a slip mixture. The existence of grog within grog is clearly shown, and on the outside of the block is a line which might at first sight be mistaken for a crack. The part where the piece has been masoned was marked in the same way. The cut was made and the section polished to show how far this mark penetrated.

The lines are due to a dry mould and the way filling was carried out. The slip was brought to the mould six buckets at a time on a wagon, and after each wagon-load there was a slight delay. The lines show the level reached by each load, and appear at regular intervals to the top of the piece. The marks may be avoided by ensuring a continuous supply of slip running into the mould or by wetting the face of the mould before filling.

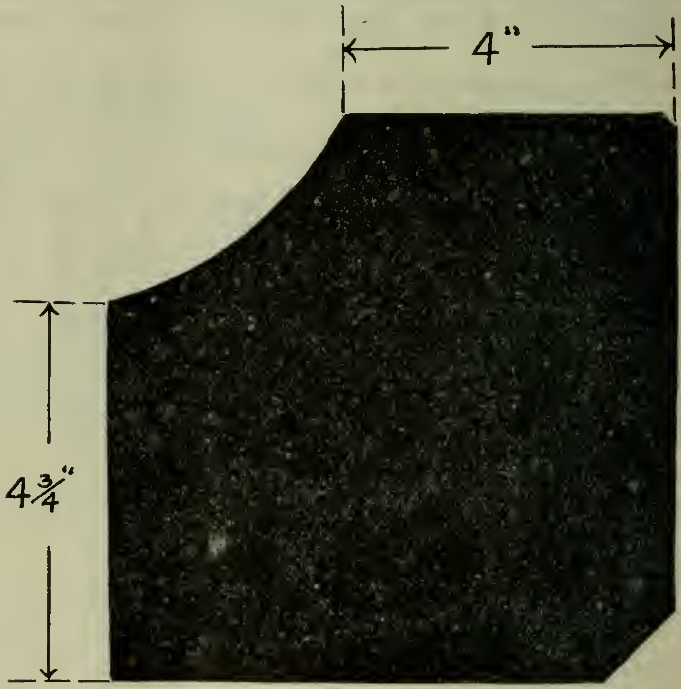


Fig. 10.

In order to cast under vacuum, it is necessary to have some sort of vacuum pump, and the necessity of maintaining the initial vacuum cannot be over-emphasised. If the vacuum drops for any appreciable period, it is impossible to get the best results. The ordinary steam jet air ejector is very sensitive to variations in steam pressure, and cheapness is its only attractive feature. The maximum vacuum obtainable by it is only 24½ inches against a closed suction branch.

The Leblanc Rotary and the Mirrlees-Leblanc Multijector air pumps are both, under suitable conditions, capable of producing a vacuum within 0·3 in. of the barometric pressure against a closed suction pipe. There are only two moving parts in the Leblanc rotary pump, and these rotate. No valves are employed. The entraining action of this pump is on the intermittent water-plug or piston principle, and is most efficient in action. The "Multijector" has a series of nozzles arranged in two sets. The first set, which only uses about 1/20 inch of the operating steam, is used to start the air in motion and deliver it into the second set at a high velocity. This apparatus is not affected by variations in steam pressure providing the pressure does not fall below that for which the apparatus is designed.

In conclusion, it should be mentioned that a cast pot dries much quicker than a pressed article, and in the author's opinion there is no advantage in taking longer than a week for drying after the piece comes out of a vacuum mould. In fact, it would probably be an advantage to put the pot into the muffle arch two days after it came from the mould; for there is less danger in firing a comparatively wet piece than firing a piece nearly but not quite dry.

The author hopes that the fact of his thoughts having a bias in a particular direction will provoke a discussion and cause a host of new ideas to arise which will eventually produce results beneficial to the industry.

Blythe Bridge,
Staffs.

Discussion.

Mr. W. Butler said that he understood some pots had been made by this vacuum casting process and tried in the glasshouse. It would be interesting to know the results of the tests. Mr. Allen replied that, so far as he knew, no pots cast under a vacuum had been tried in a glasshouse.

Mr. Edwards asked if the lecturer knew the expansion or contraction, density, porosity, and softening point of the cast clay in comparison with the clay prepared by the usual methods. Further, how much grog was necessary to get a good cast pot. In reply, Mr. Allen said that he had not measured the physical constants referred to. The amount of grog necessary depended on the kind of pot required. It was possible to cast a pot consisting wholly of clay or wholly of grog, and any proportion in between these two extremes could be cast as desired. Referring to the softening point, he said that deflocculated clay would withstand a very much higher temperature than the untreated clay, and only became vitreous at about 1700°.

In reply to a question about the costliness of the electrical process of separating clay, Mr. Allen admitted that it was expensive, but said that whether the electrical method was the only one which would obtain the desired result was open to doubt, and further research in this direction was proceeding at the present time. The important point to remember was that it was possible to improve the quality of clay by the process of deflocculation. The Americans were using the deflocculating process extensively, but did not use the electro-osmosis machine.

Mr. J. G. Hill asked if it were proposed to make pots by this process for delivery to glass manufacturers? Mr. Allen said that pots had been made but not yet tried by glass manufacturers. He was prepared to lend the necessary moulds and apparatus to any glass manufacturer who had the requisite materials available and who would care to try the process and test the pots.

Mr. J. Wilkinson asked if it were possible to get a smooth, close-grained surface on the inside of the pots? Mr. Allen said it was a very easy matter to get a close texture on the inside of the pot by filling it a second time with a suitable slip. He did not think a smooth surface was so important in effecting the life of a pot as the close and homogeneous structure of the material.

Mr. J. H. Davidson asked how long a vacuum mould would last as compared with the life of the plaster mould used in the ordinary casting process. Mr. Allen replied that he was not able to state the answer in figures, but the vacuum mould had a very much longer life than the ordinary mould. He was inclined to ascribe this to the fact that no salts were allowed to crystallise in the walls of the mould, and that it was never allowed to become saturated with water.

Mr. Allen was asked whether he had found that pots cast by this process had walls of varying thicknesses, and in reply said that it was not very easy to get any variations in the thickness of the walls, and that specially designed moulds had to be constructed in order to get the increase in thickness that was necessary on the bottom of the pot and in the lower portion of the sides.

Asked how the cost of casting compared with the cost of making pressed pots as at present, Mr. Allen said that in other branches of the fireclay industry it was found that even when the cost of moulds was included there was a saving of between 30 and 60 per cent.

Dr. A. B. Searle said that the idea of casting pots was not new. He was casting pots in Germany fifteen years ago, using the same method but for the application of the vacuum. The purified material was suspended by an electrolyte, and the clay slip was poured into a mould; but he was limited to casting open pots, as he could not cast the top on the closed pots.

Mr. Allen replied that he only claimed novelty in the manner of applying the vacuum to the casting process. The casting of pots in the ordinary way was known sixty years ago. The application of reduced pressure had also been used previously in the manufacture of thin porcelain vases, but in this case the vacuum was just sufficient to enable the vases to keep their shape until dry, and only applied after the clay had been deposited. A vacuum mould had been tried at Stoke years ago, but it had been abandoned owing to the difficulty of maintaining a satisfactory vacuum. In the present method of applying the vacuum it was easily maintained.

X.—*Some Phenomena of Pot-Attack.*

By Walter Rosenhain, B.A., D.Sc., F.R.S. (of the National Physical Laboratory.)

(*A Lecture delivered at the London Meeting, May* 21*st*, 1919.)

In taking for the subject of this lecture "The Phenomena of Pot-Attack" I propose to give an account of the work on this subject which has been carried out, under my general direction, at the National Physical Laboratory, principally by Mr. E. A. Coad-Pryor, Mr. V. H. Stott, and Miss Alice B. Taylor. This work has formed an important part of the general research on the methods of producing optical glass which, initiated under a grant from the Board of Trade in 1915, has since been continued under the auspices of the Department of Scientific and Industrial Research. One of the main objectives with which that research was begun consisted in an endeavour to arrive at an ideal pot which—either as the result of the use of special material or by special treatment—should resist pot-attack to a very high degree; it was hoped to arrive, if possible, at a pot which might successfully resist even the attack of the more violently active types of glass, such as those containing high percentages of lead or barium together with boric oxide. In our endeavour to produce pots or pot-linings having such a high degree of resistance, it became obvious that we must first study the exact nature of the attack of molten glasses on pots of various kinds, in order to arrive at an understanding of the mechanism of attack and of the conditions governing it. While we are not yet in a position to say more than that we have made some appreciable progress towards solving the problem of finding an ideally resistant pot, the careful and detailed experimental study of pot-attack which we have made appears to us to have thrown an entirely new light on the whole question of the interaction of molten glass and clay. This knowledge, and the conclusions which can, we believe, be based upon it, appear to be of such wide and general applicability to all branches of glass manufacture that it seems desirable to place these results before the industry, although, strictly speaking, they constitute rather a by-product of our main investigation. In scientific research, however, particularly when it is aimed at the solution of a direct practical problem, such by-products are not to be despised or neglected. The main objective sometimes proves much more difficult to attain than is at first anticipated, while valuable results often appear on the way.

The study of pot-attack is not, of course, in any sense novel; glass manufacturers have all met with painful examples of pots prematurely "drilled," and they and their laboratories have, no doubt, devoted anxious care to the somewhat rueful study of such cases. But the examination of a drilled pot is rather of the nature of a *post-mortem* inquiry, with the added disadvantage that very possibly the cause of death has disappeared long before the examination can be made. The inevitable consequence is that the views based on such cases are not really supported by any considerable body of sound evidence, and are, therefore, little more than opinions of more or less weight. The only really satisfactory method of studying such phenomena as occur in the attack of molten glass on clay consists in conducting the attack under accurately controlled and standardised conditions of temperature, time, atmosphere and composition of glass, and then interrupting the operation and removing the pot from the furnace, breaking or cutting it up, and making detailed examinations both with the unaided eye and by means of the microscope, and bringing definite methods of measurement into play. It is obvious that such a programme cannot well be carried out in a works under manufacturing conditions, nor on any large scale, on account of the great expense involved. When, therefore, we found it necessary to take up the study of pot attack by such experimental and exact methods, we at once realised that we should aim at making careful and accurately-controlled experiments on the smallest scale which would exhibit the characteristic phenomena, leaving the translation to the large scale and application to works practice for a later stage of our work. In order to secure the requisite accuracy in the control of temperature and furnace conditions, the whole of the experiments here referred to have been carried out in a small electric furnace of a type specially developed at the National Physical Laboratory for work of this kind. This furnace, in which the "resistance heater" consists of a wide vertical tube built up out of rings of graphite, has been described elsewhere.* For the temperatures used in this work, lying between 1230° and 1280°, the control of temperature was found to be very easy, and the temperatures were in every case measured by means of a platinum thermo-couple. As regards atmosphere, the furnace was provided with an inner liner tube or muffle, made of silicon carbide, and between this and the graphite rings a supply of nitrogen was introduced. The muffle-tube and the nitrogen jacket thus served to isolate the melting-space from the carbon of the rings, and the atmosphere of the melting-space was thus mainly filled with air, only small amounts of carbon dioxide and carbon monoxide being present. Glasses containing high percentages of lead could be melted in this furnace without any signs of reduction. In order, however, to ascertain whether the observed phenomena were likely to be affected by the furnace atmosphere, a few check experiments have also been made in a furnace heated by gas and an air-blast; no appreciable divergences were, however, found.

The Type of Refractory Material Studied.

The next point to be decided was the choice of the pot material and of the standard glass or glasses to be used for the experiments. For the material of the pot it appeared desirable to employ a refractory of the type ordinarily used for glass pots, that is to say, a material of the "clay" type; but a preliminary study of ordinary fireclays rapidly convinced us of their entire unsuitability for use as a "standard" for our purpose, owing to the frequent presence of impurities and defects arising from them. We were thus led to adopt the purest and most refractory form of clay, that is, very pure China clay. A "rational" analysis of this material gave the following result:—

Clay substance	92·25	per cent.
Felspar	3·57	,,
Quartz	4·18	,,

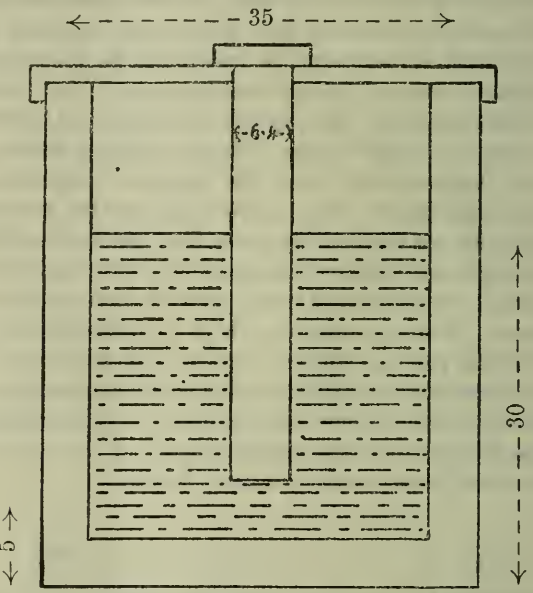
---

* A detailed description of this furnace is published in the Transactions of the Faraday Society, 1919.

Pots were made of this material by a slip-casting process in open plaster moulds, the slip being composed of

60 per cent. China clay
40 ,, Grog

with the usual additions of deflocculators. The grog was obtained by previously firing balls of the same China clay in a special kiln to above cone 18, and subsequently grinding and sieving through a 60-mesh sieve. The size of pot employed was quite small, as indicated in the dimensioned sketch (Fig. 1), which shows a vertical section of the pot.



Dimensions in mm.

FIG. 1.

In addition to these small pots, experiments on attack were made simultaneously by immersing in the molten glass in such a pot a vertical cylindrical rod, also shown in Fig. 1. These rods were cast in the same manner as the pots and were supported during the experimental meltings by being passed through a central hole in a lid of the same material which fitted over the pot.

The Choice of Standard Glasses.

The choice of the standard glasses the attacking action of which on the pots and rods was to be determined was a matter of greater difficulty. Our first choice, however, was made on grounds based on the aspects of our work relating to optical glass. It is well known that glasses very rich in barium oxide exert a most powerful attack on clay of all kinds at high temperatures, and we accordingly selected a glass of this kind in order to subject our pot materials, and such protective linings as we wished to study, to the severest possible test. These glasses have the further advantage, from the experimental point of view, of being very fluid at quite moderate temperatures. The first type of glass used, which we called "S.G.4," had the following composition:—

NaO_2	3·8	per cent.
BaO	56·7	,,
B_2O_3	17·3	,,
SiO_2	22·2	,,

corresponding with $Na_2O,6BaO,4B_2O_3,6SiO_2$.

Having obtained somewhat striking results from the series of experiments and measurements made with this extreme type of glass, we next wished to ascertain whether the same phenomena, governed by the same definite laws, would be met with when a glass having a much less violent action was employed. The glass used for this second series of measurements has the following composition (S.G.6):—

Na_2O	3·6	per cent.
BaO	39·5	,,
B_2O_3	12·0	,,
SiO_2	36·1	,,
Al_2O_3	8·8	,,

corresponding with $Na_2O,3BaO,2B_2O_3,7SiO_2,Al_2O_3$.

In addition to these two glasses, which were alone employed for longer series of quantitative experiments, check experiments were also made with a large number of glasses of entirely different compositions, including a series of "flint" glasses, an ordinary soda-lime glass, and other compositions aimed at securing particular densities. It may be remarked at once that the results obtained were so consistent and uniform that the conclusions to be drawn from them may safely be regarded as applicable to all ordinary varieties of glass.

The Mode of Carrying out the Experiments.

Since the object of the research was the study of the action of molten glass on clay, and not the action of raw materials of various kinds, we adopted the system of preparing the glass in every case by previously melting it in China clay pots considerably larger than those described above. The glass thus obtained was granulated by pouring it, while melted, into water. This "water cullet" was then the only material introduced into the small experimental pot, and only a single filling was used. When melted, this left the pot about two-thirds full, which was sufficient for the purpose.

The maintenance of a standard time of exposure to the standard temperature in each successive experiment was a matter of some little difficulty. This was overcome as follows: The cold pot was packed as full as possible of the finely-granulated cullet and the rod and lid were then placed in position. The little pot was then placed inside the furnace, being arranged inside a larger pot, the lower part of which was filled with fine, pure silica sand. The small experimental pot stood on this layer of sand and showed no tendency to adhere to it, while in cases where the little pot was pierced during the experimental heat, the sand absorbed the molten glass which ran out, thus avoiding damage to the furnace.

When the pot, filled with cullet, was in position, the temperature of the furnace was very gradually raised—in the course of about an hour—to 700°, in order to avoid the risk of cracking the pot. Up to this temperature there was no appreciable action between the glass and the pot, while rapid heating from this temperature upwards seemed to entail no risk of cracking the pots. Thanks to the properties of the electric furnace, it was therefore possible to raise the temperature from about 700° to the standard temperature (say, 1230°) in ten minutes or a little less. By taking the time of exposure as from the moment when the thermo-couple indicated 1200°, the total time could be recorded to within the nearest minute, a degree of accuracy which for an exposure of two hours appeared to be sufficient.

The aim of the present research having been, from the outset, the *quantitative* study of pot-attack, the measurement of the pots and rods before and after attack became a matter of fundamental importance. As regards the pots, measurements were confined to four points marked on the outside of the bottom by four slight specks of cobalt. At the points thus marked, the thickness of the pot before use was carefully measured by means of a micrometer. The rods were similarly measured at a number of points; the diameters varied a little from point to point, but a sufficiently close mean could be taken. The measurement of the thickness of both pot-bottoms and rods after attack was a more difficult matter. In the first place, they could not be freed from adhering glass, even when the molten glass was poured away at the end of the experiment, while the surface after attack was often very irregular. The measurements were therefore made by cutting sections through the

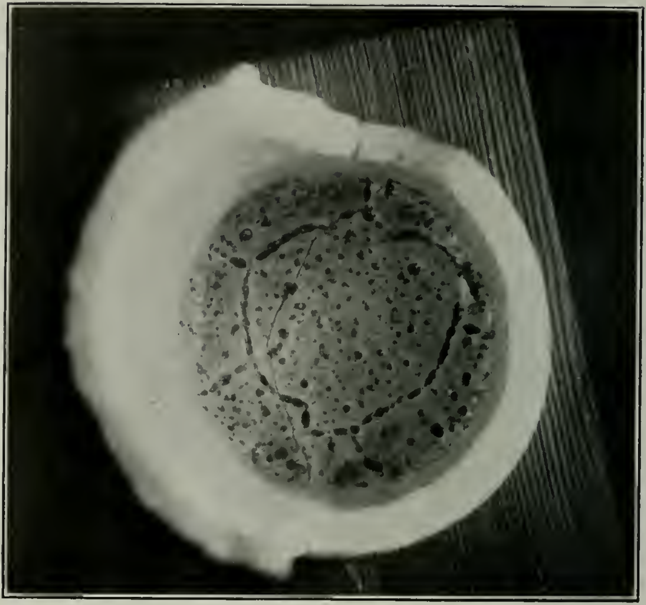


FIG. 2.

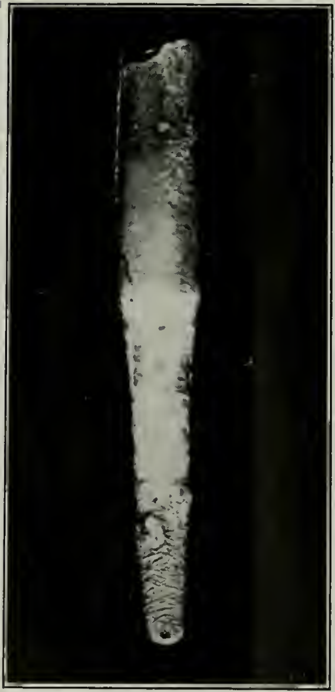


FIG. 3.

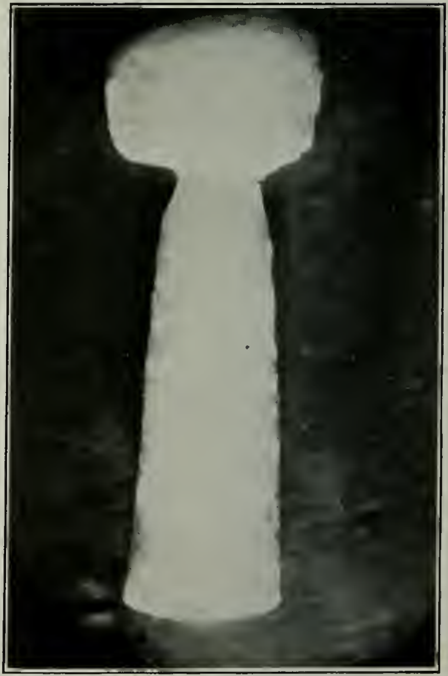


FIG. 7.

[*To face p.* 99.

pots and rods. In the case of the pots, these were cut through the marks mentioned above, while in the case of the rods, successive sections at different depths were prepared. These sections were placed under the microscope and either photographed or drawn with a camera-lucida at a suitable magnification (about 10 diameters). On the photographs or drawings areas could then be measured with a planimeter, and very accurate values could be obtained for the mean thickness of the bottom of a pot over a given width by simply dividing the area found for this width by means of the planimeter by the width, the quotient being the mean thickness. In the case of rod-sections the mean diameter was calculated from the area found by the planimeter, the "depth of attack" being the difference between this mean diameter and the original diameter of the rod.

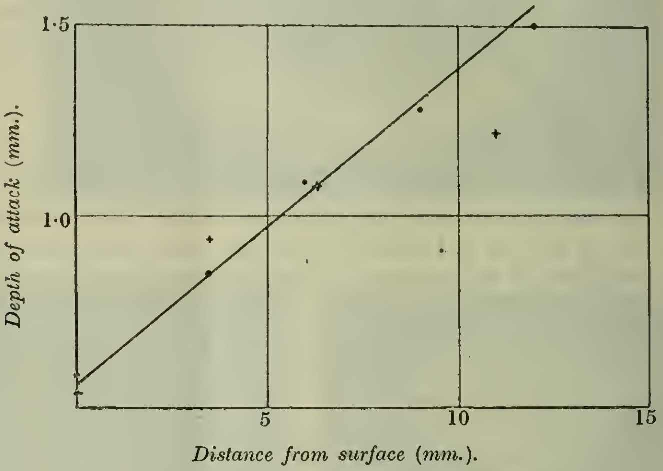
Differential Attack on the Pots and Rods.

Before describing the results of measurements, it will be convenient to mention two very definite observations which obtruded themselves as soon as the attacked pots and rods were examined. In the first place, it was seen that the main attack on the pots had taken place on the bottom and lower parts of the sides. In some cases the attack on the bottom took the form of a series of pits or incipient drills of varying depth, lying approximately on a circle concentric with the pot itself, and at a short distance inwards from the sides. An example of this type of attack is shown very well developed in the photograph (Fig. 2), approximately natural size. In other cases the attack on the bottom is more general. The fact that pots are most severely attacked on the bottom is, of course, well known to glass-makers, and the observation that the same thing occurs in these small experimental pots serves in some measure as an indication that the mode of action is much the same in pots of widely different dimensions.

The second striking fact was that the rods which had been immersed in the molten glass, so far from showing anything like uniform attack over the immersed length, came out with a strongly-marked taper which sometimes reduced them to mere points at the lower end. An example of such an attacked rod is shown in the photograph, Fig. 3, approximately natural size. This observation that the rate or depth of attack increases with depth in the glass is strongly confirmed by our observations on a number of pots in which glass-meltings on a much larger scale had been carried out. Here, there was a corresponding downward taper in the residual thickness of the pot walls extending over a depth of more than

20 cm. in a pot containing about 15 kilos. of glass. Stirring rods, subjected to long exposure while stationary at high temperatures, in these larger pots showed a taper of the same kind.

The existence of the taper produced by "pot-attack" in the case of immersed rod is very clearly borne out by the series of measurements which have been made, in the manner already indicated, on successive horizontal sections cut from the rods. The results of one such series of measurements are shown in the graphs of Fig. 4. The plotted points on this figure show, on a very much magnified scale, the depth of attack as ordinate against depth below the surface of the glass as abscissa. Data obtained from two cones are shown, one set being indicated by crosses and the other by round dots. Measurements of this kind are necessarily open to minor fluctuations arising from local inequalities of attack, but, on the whole, the points shown on Fig. 4 are best represented by a straight line running at an angle only slightly less than 45° to the horizontal. The data of Fig. 4 relate to pure China clay, which had been fired to cone 17 and the porosity of which, as measured before the rod was immersed in the glass, was 28·5 per cent. It is interesting to note that this material has what may fairly be described as an exceedingly high porosity; yet the results as regards attack by molten glass were quite as good, that is, attack was resisted as well, as those obtained with any other clay refractory employed in these experiments—a result which suggests that porosity may not play so large a part in the phenomena as has been supposed.



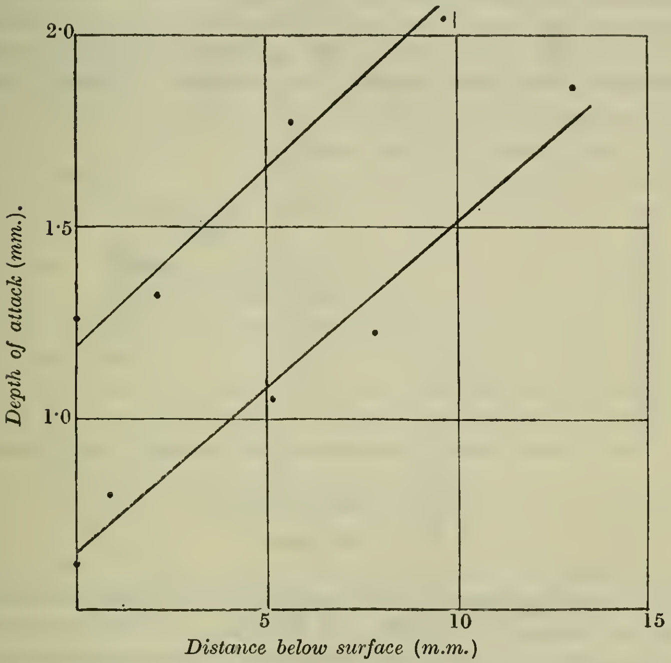
China clay. Cone 17. *Porosity* 28·5 *per cent.*

FIG. 4.

For the sake of clearness, the data represented in Fig. 4 have been confined to those obtained from measurements of two individual rods only; a number of other rods of the same material have been tested under similar conditions, and the results in all cases agree substantially with those indicated in the figure, only isolated points here and there lying appreciably away from the mean line.

Next, in order to illustrate the influence of somewhat different treatment and condition of the refractory material, we may show the two graphs of Fig. 5. Here the glass used (S.G.4) and the temperature (1230°) were the same as in the experiments represented on Fig. 4, but the rod the measurements of which are indicated in the upper graph was made of a China clay batch containing only 30 per cent. of grog instead of the "standard" 40 per cent., and was fired at cone 16. This had a porosity of 30 per cent. The lower graph refers to a rod in which 7 per cent. of felspar had been added to the standard China clay material. This addition had been

China clay. Cone 16. *Porosity,* 30 *per cent.*



China clay 93 *per cent. Felspar* 7 *per cent. Cone* 27
Porosity 16·2 *per cent.*

Fig. 5.

made in order to obtain a highly vitreous material of the nature of very hard porcelain; and, in order to secure vitrification and a low porosity, this was fired up to cone 27. The resulting rod had a porosity (real, not apparent) of only 16 per cent. It will be seen that the plotted points are in both cases well represented by straight lines again running at an angle very near to 45° to the horizontal. The lines representing the two materials are substantially parallel, but, on comparing Fig. 5 with Fig. 4, it will be seen that the graph of the very vitreous material is almost identical with that for a China clay having a porosity of 28 per cent. On the other hand, the rod in which there was a lower percentage of grog underwent a somewhat more rapid attack. This, however, is probably due to the lower proportion of very highly-burnt grog rather than to the actual porosity, which is only slightly higher than that of the material referred to in Fig. 4. Further, in comparing the two graphs of Fig. 5, it must be borne in mind that although the vertical distance between them indicates a constant difference in actual depth of attack, this difference is important only where the total depth of attack is very small. At any considerable depth below the surface of the glass the percentage difference between the two would become negligible. A real difference in the slope of the two graphs, however, would make a very large difference where the depth becomes considerable—provided we were justified in assuming that the approximation to a "straight-line law" which these measurements indicate is applicable to considerable depths. There is, however, some doubt whether this assumption is correct, and it must be applied cautiously until experiments on much deeper pots have been made to test its validity.

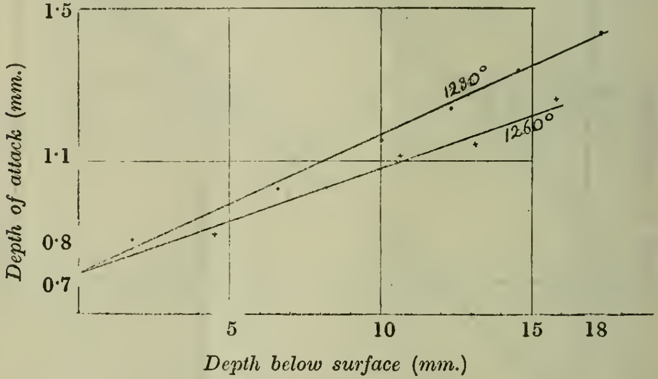


Fig. 6.

In Fig. 6 are shown two graphs representing the data obtained by experiments made to test the effect of using a different glass (S.G.6) and by working at different temperatures, the material used being the "standard" China clay body already referred to in Fig. 4. Owing to the slower action of this glass, a slightly higher temperature and longer time (five hours instead of two) were required, and the upper graph shows the results of exposure at 1280° and the lower at 1260°. On comparing these two graphs with those of Figs. 4 and 5, it is at once evident that, although the "straight-line law" still holds, the slope of the lines is much less, thus indicating that, even at the higher temperature employed, the attack by this glass is still much less severe than that of S.G.4. The much greater regularity of the attack produced by the less vigorous glass is also indicated by the fact that the observed points lie much more exactly on the mean line. The effect of a change of temperature is also very well marked, the line representing attack at 1280° being very decidedly steeper than that relating to attack at 1260°.

The three figures just discussed (Figs. 4, 5, and 6) embody the results of a very large amount of laborious and accurate work, and at first sight it might appear that the results obtained did not throw a very great amount of new light on the whole question of pot-attack. But, even in itself, the demonstration that the rate of attack is for small depths, at all events, proportional to the depth of immersion in the glass, constitutes an important step forward in our knowledge of the manner in which molten glass attacks clay bodies immersed in it. This result is all the more important because it is distinctly unexpected. The fact that it has not previously been discovered, so far as I am aware, is probably due to the circumstance that other phenomena which occur in ordinary glass-works practice serve to mask this fundamental phenomenon completely. If, however, we are to solve the problem which pot-attack presents to us, it is an essential first step to study it in some such way as we have tried to do and to arrive, as we believe that we have arrived, at a recognition of its fundamental law. In order, however, to carry the matter further, it is necessary not only to recognise the facts of measurement, but to endeavour to find a satisfactory explanation of the manner in which they are brought about. In doing this, we are obliged to work on some hypothesis as to the inner nature of actions which, in the case of molten glass, are not open to direct observation, and subsequently to test the validity of our hypothesis by every experimental means available to us. If we can formulate such an hypothesis which will stand the severest tests of this kind, we may well hope that it will furnish us with guiding principles which may be profitably applied to industrial practice. To arrive at a "theory of pot-attack," therefore, is no mere matter of academic speculation, but one of very real and direct importance to those who have to use glass and clay together; a sound theory of this kind may well prove to be of really fundamental importance to the whole industry.

The Explanation of Localised Attack.

The first suggestion arising from the consideration of the "straight-line law" of attack is, naturally, the idea that the solubility of clay in glass increases simply with hydrostatic pressure. This view, however, appeared to be so entirely contrary to the known behaviour of other solutions that there was very considerable hesitation in accepting it even tentatively. There was, further, a remarkable additional phenomenon which we met with in certain cases which did not at all fit in with this suggested effect of pressure, namely, that in some cases we found a marked local attack at the level of the surface of the glass, resulting in the formation of a groove or "neck" in the immersed rod and a groove in the wall of the pot. To harmonise this phenomenon with the "pressure" theory, it would be necessary to suppose that the gases of the furnace atmosphere played an important part in producing this grooving at the "water-line." The chemical nature of the glasses employed, namely, mutual solutions of stable oxides, did not render such a view probable, and other explanations were sought.

At this stage Mr. Coad-Pryor began to investigate this special phenomenon of neck-formation by studying the manner in which rods of other more or less soluble materials dissolved in liquid solvents. Rods of various fused salts, such as sodium carbonate, when exposed to water, and of plaster of Paris when exposed to dilute acid, were examined. The result was surprising; the rods in these circumstances also developed a taper, but in the reverse direction to that met with in our experiments with glass, that is, they assumed an Λ taper instead of the V which we had met with in glass. An example of such a rod (plaster of Paris in dilute acid) is shown, slightly magnified, in Fig. 7 (facing p. 99). In this case there is, naturally, a shoulder at the water-line, but there is also a very slight groove or "neck."

This surprising result led Mr. Coad-Pryor to watch the process of solution by which this reversed taper was obtained, and he at once saw that the whole operation was associated with a special system of very vigorous circulation which was set up in the liquid as soon as the rod was immersed in it. The liquid next to the rod became denser as some of the material of the rod was dissolved in it, and this denser liquid at once began to flow downward along the rod, being replaced by fresh, unsaturated liquid from outside. The circulation observed is roughly indicated in the sketch, Fig. 8, but it is very much more convincing to watch the process* in reality.

The character of these currents at once explains the reversed or Λ taper of these rods. At the top, the rod is constantly washed by a stream of solvent free from the material of the rod; as the current washes down the sides of the rod, the liquid becomes increasingly loaded with dissolved matter, and therefore becomes decreasingly active as a solvent, with the result that the rod is most rapidly attacked near the top and to a decreasing extent with increasing depth.

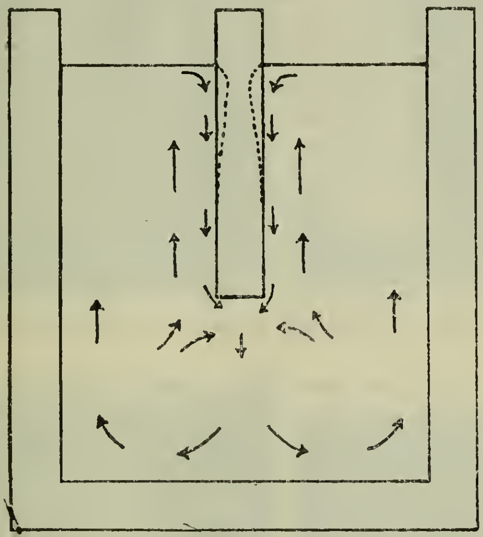


FIG. 8.

The reversed or Λ taper is thus fully accounted for, but it remains to account for the formation of the V taper. Mr. Coad-Pryor soon hit upon the explanation, for if by any means the direction of the circulation could be reversed, then the taper would also be reversed. But what conditions are required for bringing about this reversal? Simply this, that when the density of the liquid is increased by taking the material of the rod into solution, we have a downward current flowing along the surface of the rod;

---

* At the lecture the process was demonstrated by the aid of the lantern.

if, however, the density of the solution were diminished by taking the material of the rod into solution, we must have an upward current flowing along the face of the rod. Now, in the case of water and aqueous solutions generally, this is not easily accomplished; such solutions almost universally become denser when any solid substance is dissolved in them. By the use of heavier solvents, such as carbon tetrachloride, however, the desired reversal of this state of affairs could be obtained. When either paraffin wax or naphthalene is dissolved in this liquid, the resulting solution is less dense than the pure liquid. Accordingly, when rods of these substances are immersed in a vessel containing carbon tetrachloride, the resulting attack produces a V taper exactly similar to that which we had found in the case of clay and glass. In the case of paraffin wax, a simple V taper is produced, as shown in Fig. 9, while in the case of naphthalene the V taper, together with a well-marked groove or neck, is produced, as seen in Fig. 10.

As it might be suggested that molten glass is much more viscous than the solutions used in these experiments, the effect of rendering the water solutions more viscous by the addition of glucose was tried. The type of attack was unaltered, but the time occupied was materially increased. Even when the viscosity had been very much raised, the circulating currents could still be seen quite markedly.

The strict analogy of these phenomena as seen in the attack on rods of wax and naphthalene in the organic solvent with the phenomena seen in the case of glass is further borne out if we consider the relation of the densities as they exist in glass. In the experiments where V tapers have been obtained, the glass was in every instance a material of relatively high density (3·75 in the case of S.G.4 and 3·2 in the case of S.G.6), while the substance undergoing solution (China clay) is of relatively low density—approximately 2·6. Glass which takes China clay into solution, therefore, becomes lowered in density, with the inevitable result that it is displaced upwards by the denser glass outside the immediate vicinity of the clay. A system of circulation similar to that seen in the solution of wax in carbon tetrachloride must, therefore, be set up, and the V taper is the immediate and direct result.

The chain of evidence correlating the behaviour of rods in molten glass and in the organic solvent has, however, been carried much further. In the first place, we have the analogy both to the behaviour of paraffin wax, where no neck is formed, with the behaviour of the barium glasses, such as S.G.4 and S.G.6, where also no neck is produced, while in the case of the flint glasses a very

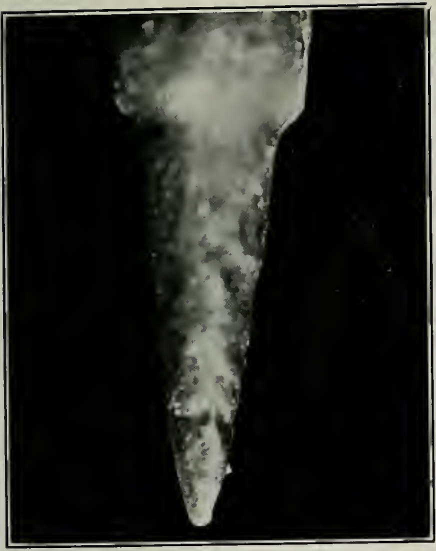


FIG. 9.

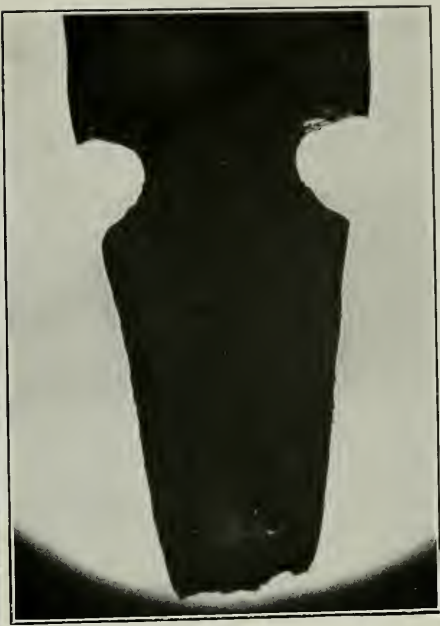


FIG. 10.

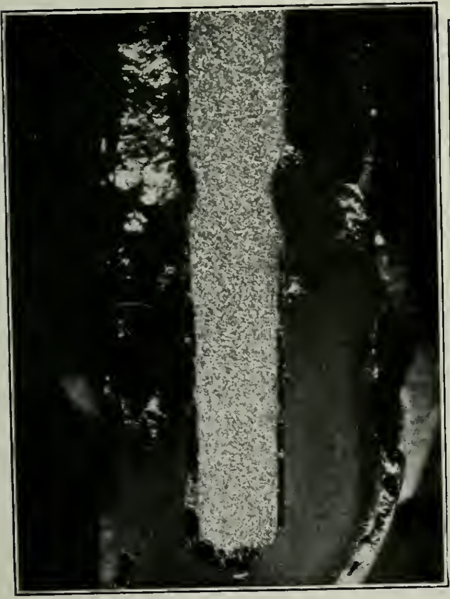


FIG. 11.

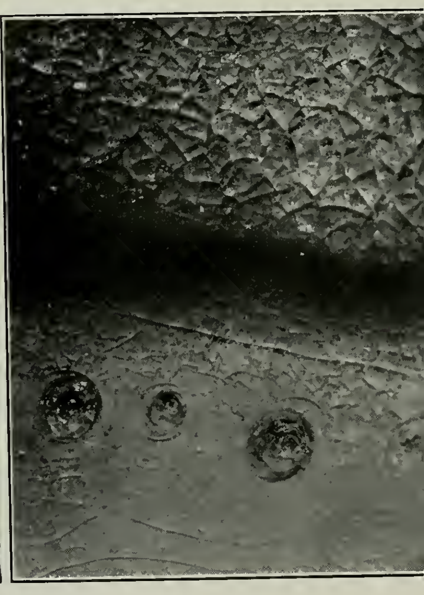


FIG. 13.

[*To face p.* 10

decided neck is formed in the same manner as that already illustrated in regard to naphthalene in carbon tetrachloride. An example of this kind, showing the section of a rod in which a "neck" has been formed as the result of attack by flint glass, is shown in Fig. 11 (facing p. 106). Further, however, it has been found possible to reproduce in the case of glass and clay the reversed or A taper typically met with in those cases where the solution is denser than the solvent. If the whole theory of the action of currents arising from differences of density is correct, then if a rod is immersed in a molten glass of very low density, that is, considerably lower than the density of China clay, the solution of clay in such a glass should increase its density and the same type of circulation should be set up as that which is met with when a rod of sodium carbonate is dissolved in water, with the formation of an A taper. Advantage was taken for this purpose of the very low density of boric oxide, and various borate glasses very high in boric oxide were tried. The resulting taper was in all cases of the reversed or A type, which the theory had led us to expect.

The formation of the groove or neck at the "water-line," both in the case of naphthalene in the organic solvent and in the case of clay in flint glasses, appears also to be the direct result of a particular type of circulation. When we watch a rod of naphthalene dissolving, the presence of very rapid and vigorous surface currents is at once detected, while paraffin wax dissolving in the same liquid appears to produce no serious surface currents. It would thus seem that the chemical nature of the dissolved substance has an important influence on the exact disposition of the surface currents in particular. One might perhaps hazard the suggestion that the surface currents may be due to the effect produced upon the surface tension of the liquid by the entry of the solute; it is well known that the effect of dissolving another substance in a liquid upon the surface tension of the liquid varies very much. Thus the well-known experiment of placing a small piece of camphor on water, when, as the result, it is believed, of changes of surface tension, the fragment of camphor moves about violently, suggests that powerful surface currents may be produced by disturbances of surface tension produced by solution. As yet, however, we have no direct evidence that such disturbances are produced in the surface tensions of molten flint glasses. Up to the present, in fact, we know far too little about the surface tension of molten glass, although that property exerts a very powerful influence on glass during many industrial operations.

The explanation of the phenomena of pot-attack which is furnished when we understand the nature of the circulations which arise as the result of changes of density brought about by processes of solution is applicable in yet other directions. Thus, in the case of a pot in which glass of any ordinary density is melted, there will be an upward flow of glass along the walls of the pot. Such an upward flow must, however, be compensated by a corresponding downward flow, and, apart from other disturbing causes, this will occur quite near the pot walls, much in the manner indicated diagrammatically in the sketch, Fig. 12. Now we have already seen that attack becomes very marked at those places where a current of solvent first strikes against the body undergoing solution. We should therefore expect a particularly powerful attack on the bottom of the pot generally, and particularly along a circle concentric with the pot walls. That such attack does occur is well known, and a good example has already been shown in Fig. 2.

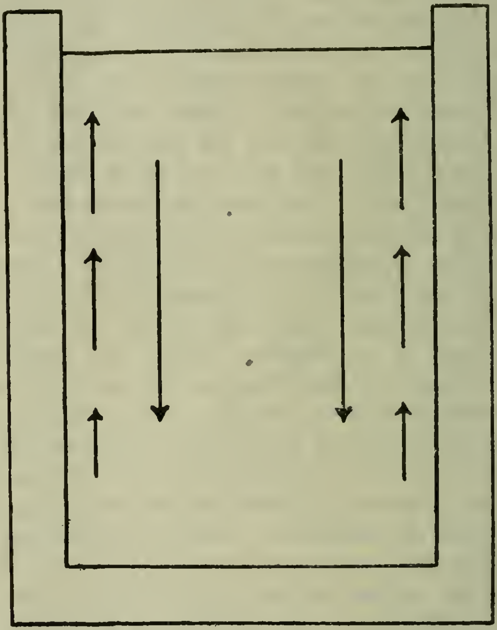


FIG. 12.

The "Drilling" of Pots and its Cause.

The very phenomenon of "drilling" itself, particularly the formation of deep vertical drill-holes in the bottom of a pot, is also readily explained by the "circulation" theory. Once a shallow depression is formed in the bottom of a pot, this will deepen itself relatively rapidly unless the circulation in the pot is so vigorous as to draw the glass out of the little depression continually. If the glass is allowed to remain in such a depression and is unaffected by the currents sweeping over the tops of the little hole, then each hole will reproduce the entire phenomena of a small pot, with an accentuation of the attack on the bottom which will grow in intensity as the depression deepens. Whether there will be local drilling or not, therefore, seems to depend principally upon the velocity and location of the main circulating currents in the pot itself. Local defects will, of course, produce local failure if they are sufficiently serious, but the insight into pot-attack phenomena which we have now gained certainly suggests that once a small surface inequality has been formed, this may develop into a deep drill-hole, even in the entire absence of any local defect in the pot.

A further point of interest in regard to drilling may also be mentioned. In those experiments with specially light glasses, in which a reversal of the usual density relations brought about a reversal of the usual circulations, resulting in the formation of an A taper instead of a V taper, there were never signs of appreciable attack or of drilling at or near the bottom of the pot, but, on the contrary, serious drilling was observed just below the surface of the glass, again at the point where the current of fresh glass strikes the surface of the clay. This feature is illustrated in Fig. 13 (facing p. 106), which is a magnified photograph of the pot wall at the surface-level; the dark band showing a vague outline is the groove or "neck," while the circular spots below it are drill-holes. The surface of the pot as photographed was still covered with a thin layer of glass which had cracked during cooling.

The Protection of the Vulnerable Areas in Pots.

Somewhat special interest and importance attaches to one of our most recent experiments, which has not only served to confirm in a very striking manner the correctness of the whole theory of circulating currents and their effect on pot-attack, but also indicates the possible direction in which direct practical applications of the ideas put forward here may ultimately be made; for it is evident that if we have arrived at a true understanding of at least a predominatingly important factor in pot-attack, we may hope to limit and control the incidence of such attack, and thus to render it far less harmful than it is at present. The experiment in question is based on the conception of the cause of severe attack and drilling on the bottom of a pot resulting from the incidence of the downward circulating currents. If this view is correct, then, if we can protect the bottom of the pot by covering it with a material which is highly resistant to solution by molten glass, the bottom of the pot should be protected. If, however, the protecting layer is so placed that the current of glass, after flowing over the insoluble protecting layer, impinges sharply against the sides of the pot, then we must anticipate that the drilling will be transferred from the bottom to the sides at that point. The experiment was made in one of our little "Standard" pots by placing in the bottom of the pot a thin disc of a zirconia body containing about 96 per cent. of zirconia. The presence of this disc, merely lying in the bottom of the pot, which it fitted fairly closely, entirely protected the bottom, but the pot was drilled at the sides just at the level of the upper surface of the zirconia disc. It is this drilling of the sides of the pot near the bottom, resulting from the deflection of the currents by the presence of the zirconia disc, which affords such a striking confirmation of the accuracy of the conceptions as to circulating currents which have here been put forward.

From the direct practical point of view, also, this experiment offers to open up important possibilities. In the form in which it was carried out, the dangerous current was merely deflected from one point to another and still allowed to impinge directly upon the side of the pot. A carefully designed deflector, however, which could no doubt be arrived at after a few trials, may make it possible to divert the current in such a manner as to avoid all local attack resulting from the direct impact of a circulating current; and, if such control is possible, the solution of many of the difficulties arising from pot-attack would be in sight.

Various possible devices of this kind may be indicated. Thus, local attack near the surface of the glass might be met by the introduction of a ring of special material so constituted as either to resist the attack of the impinging currents or the protecting ring might be allowed to dissolve gradually and be replaced at intervals. Another possibility lies in the direction of loading up either the whole body of the pot or a special "guard ring" or other protective device with bodies of high density, so that when the glass dissolves them no change of density is caused in the glass. In that case the circulating currents might be almost entirely suppressed. If, on the other hand, the refractories are so "loaded" as to increase the density of the glass, the reversed currents would be set up and attack transferred—possibly—to more convenient positions where protection could be more readily applied. Such "loading-up" might be accomplished by the introduction into the clay of such dense materials as alumina or zirconia.

Further Directions for Experiment.

The present account of our work on pot-attack, while it has, I hope, served to open up a new point of view and to indicate that considerable progress has been made which promises soon to lead to important practical developments, yet serves to show how very much we are in need of further knowledge. The whole of our experimental work on this subject, even on the lines already followed up, needs much extension, particularly in regard to larger and deeper pots and to much longer periods of time. Then, too, it is evident that much further knowledge is needed in regard to the physical properties of molten glass at high temperatures. Such properties as surface tension and viscosity urgently demand determination. In the whole discussion of the subject which has been given above, for instance, the influence of changes of viscosity has not been specially mentioned; that aspect of the question has, however, received very careful consideration at our hands, and experiments have been made in order to ascertain whether increase of viscosity affects the types of circulation. So far as these experiments have gone, they serve to show that increased viscosity merely serves to reduce the speed of the currents, but does not appreciably affect the type of circulation. Viscosity, however, enters into the phenomena of pot-attack in another way. The boundary between "pot" and "glass" cannot be regarded as a simple, sharp line; while solution is taking place, there must be a minute zone of transition in which there is a very rapid change of viscosity. If the layers in contact with one another were not disturbed, a definite viscosity-gradient would be set up, the final result being the arrest of further solution except by the relatively very slow process of diffusion. The circulating currents, however, do disturb these layers, and the main effect of the high viscosity of the layers richest in clay substance must be to determine at what point the downward or upward current nearest the "pot" shall flow. If we had a better knowledge of these changes of viscosity and their variation with temperature, it would be easier to arrive at a true picture of these somewhat complicated processes. As matters stand, however, our only method of attack is to arrest the process by cooling down the pot with its adherent glass and then applying the microscope to a study of sections of the boundary region.

This method of studying the question has been developed to a considerable extent, and results of some interest have been obtained. While it is not possible to go at all fully into this aspect of the subject, it may be interesting to mention that in the sections of such glass-pot boundaries we have found layers of several types of crystalline bodies having very characteristic appearances. These crystals are, no doubt, formed during some cooling process, probably during the final cooling before examination; but once they have been identified, their existence and distribution serves as a key to the composition and concentration of the various solutions present and, to some extent, to the manner in which the various layers have been disturbed by the circulating currents. In Figs. 14, 15, 16, and 17 some typical examples of these various types of crystal are illustrated. The photomicrographs are taken at a magnification of 150 diameters, by reflected light, from polished and etched sections prepared in much the same way as those used for the examination of metals, except that hydrofluoric acid has been used as the etching reagent. Even in this form, however, these crystals are very difficult to photograph. Those shown in Fig. 14 consist of fine needles, with one crystal of an entirely different type lying among them. These are formed in the glass "S.G.6." In Fig. 15 the second type of crystal is shown in very full development; these also are formed in the boundary between "pot" and "S.G.6." In the case of flint glasses, somewhat different forms are met with. A typical example is shown in Fig. 16, while in Fig. 17 two distinct layers of crystals are shown, as well as a third layer, which is probably part of the structure of the "pot" proper; this example, and Fig. 18 also, are from a flint glass. When the mineralogical identification of these various crystals has been completed, we may anticipate that they will afford further light on the phenomena.

The X-Ray Examination of Clays and Clay Bodies.

While the investigation of the crystalline bodies which are formed in the surface layers of pots and the adjacent glass promises to open up a fuller understanding of the nature of the actions which occur during pot-attack, yet another method of studying the subject remains to be mentioned, and this, at first sight, offers certain promising features of direct and immediate practical utility. It may therefore be welcomed as a valuable adjunct to the more searching and fundamental methods with which we have hitherto dealt. I refer to the use of *X*-rays for the examination of clays and clay bodies, both before and after firing and before and after use. The powerful modern means of radiographic examination render the penetration of even the thickest fireclay

112

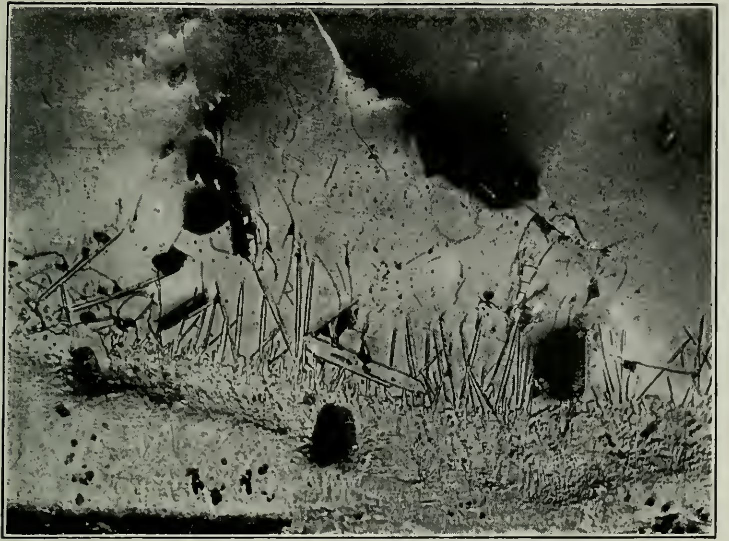


FIG. 14.

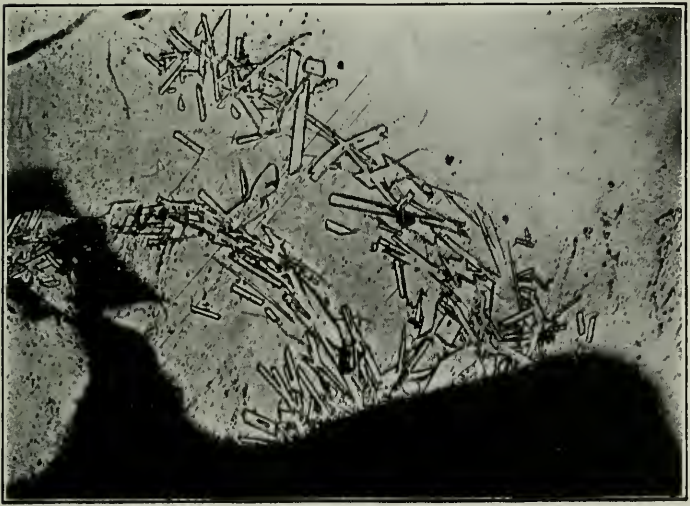


FIG. 15.

[*To face p.* 112.

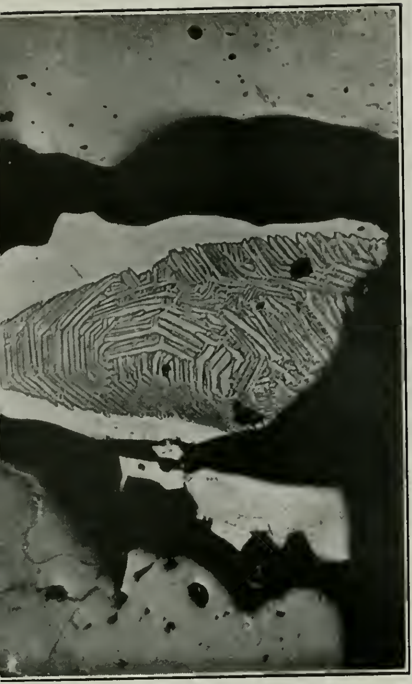


FIG. 16.

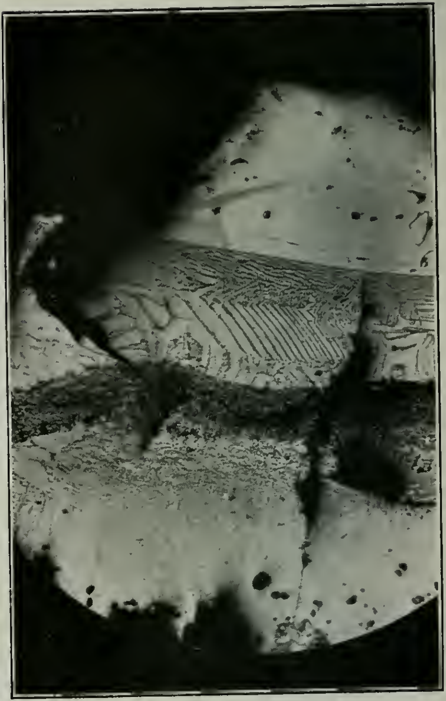


FIG. 17.

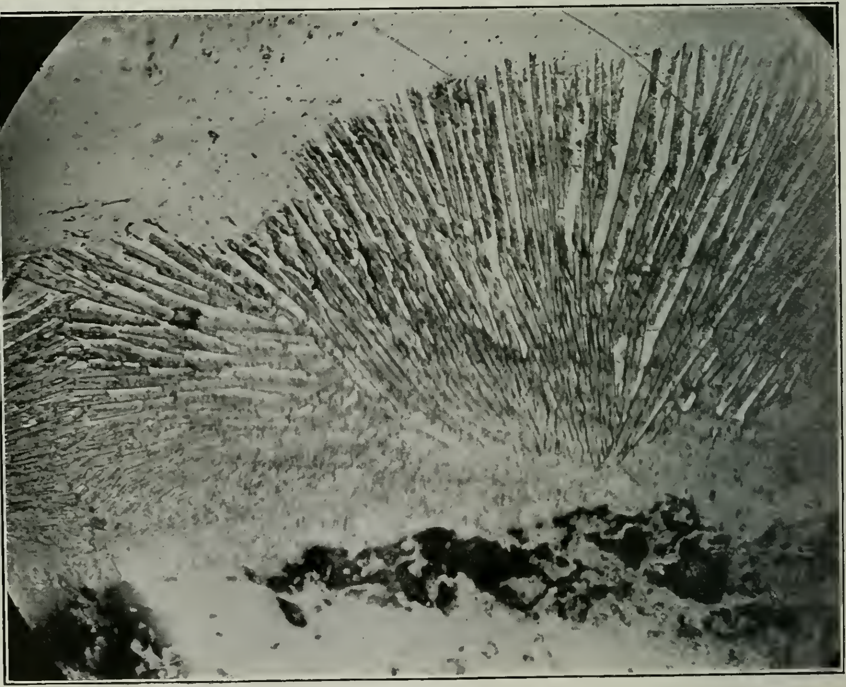


FIG. 18.

112 2.

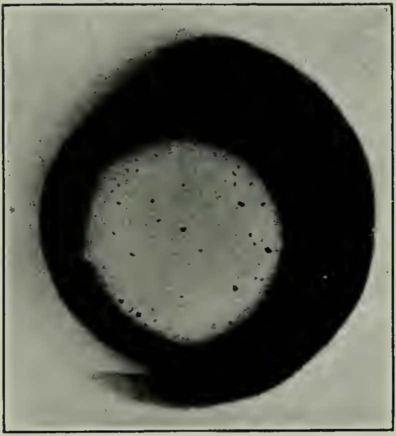


FIG. 19.

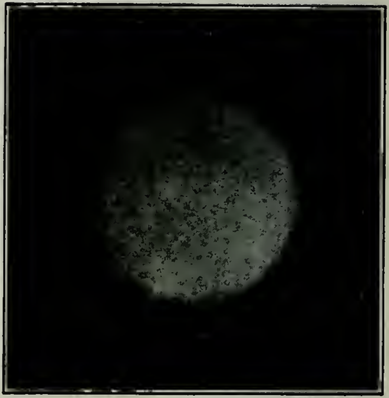


FIG. 20.

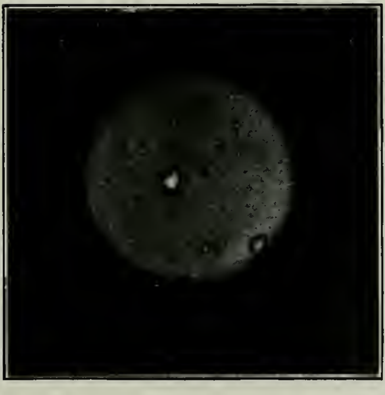


FIG. 21.

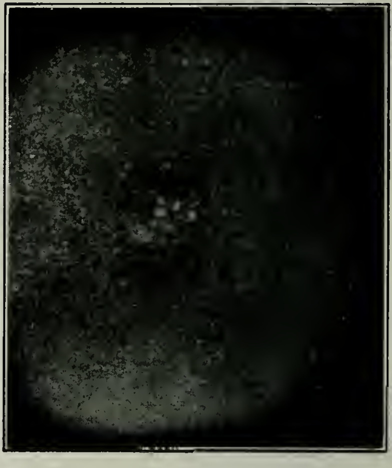


FIG. 22.

[*To face p.* 113.

articles a very simple matter, and it is possible to obtain excellent definition and exact localisation of all the features found in the material under examination. For many purposes examination with the phosphorescent screen is sufficient, but for more careful and thorough work it is far better to rely upon photography. It is interesting to find that this method of studying materials, which has already given results of very great practical value in the study of timber and of metals, even of steel in thicknesses up to 2 inches, is also readily applicable to our present purposes.

X-Ray photographs serve to show, by difference in the depth of the photographed image or by differences of brightness on the phosphorescent screen, even minute differences in density of the material through which they have passed at each particular point of the object under examination. If we subjected a slab of perfectly uniform clay, free from all defects and enclosures, to X-ray examination, we should merely see on the screen or in the radiograph an area of uniform brightness. But if at any point in the clay the X-rays meet with a region of greater density, such as would result from the presence of a small amount of iron oxide in the clay at that point, an absorption of the rays would occur at that point, and we should find a correspondingly dark spot on our screen or photograph. If, on the other hand, there were a small air bubble or cavity in the clay, the rays would pass through this region more freely than through the rest of the material, and a bright spot on the screen or photograph would be produced.

When the test is made in practice a surprising amount of detail is found on the plates, and it will perhaps be interesting to show a few examples taken from experimental pots tested at the Laboratory. Fig. 19 is from a radiograph taken of a small fireclay pot in the "green," that is, unburnt, condition. The rays passed through this pot vertically downwards while it was standing upright in its normal position. The dark ring or belt thus represents the shadow of the sides or walls of the pot seen end-on, while the light disc in the centre represents the bottom of the pot. In this will be seen a considerable number of dark specks, due to the presence of iron at those points. It should be noted that, in this state, the iron spots are mere dark, solid specks.

The next figure (Fig. 20) shows the radiograph of the bottom of a pot made of the same fireclay as that represented in Fig. 19, but in this case the pot had previously been fired to cone 15, so that it was well burnt. This photograph requires rather closer examination than Fig. 19, and may even be usefully magnified a little. If this is done, a number of spots will be found in which there is a slightly lighter central region surrounded by a definitely darker band or rim. The real nature of these annular spots is readily identified by a careful study of the burnt clay. They represent the iron spots, as did the dark patches in Fig. 19, but these spots have changed their character as the result of firing. The iron oxide has fluxed the clay immediately next to it, leaving a small central cavity. The annular spots seen on the radiograph are the *X*-ray shadows of these little defects.

Another example of a defect of similar type, but of widely different origin and of much more striking appearance, is shown in the radiograph, Fig. 21 (facing p. 113). This represents a China clay in which minute particles of plaster of Paris from the casting mould have become embedded. On firing, these have fluxed the adjoining clay, and thus produced annular spots similar to those caused by iron, but larger and more fully developed. Finally, in Fig. 22 (facing p. 113), a radiograph is shown in which air bubbles have been enclosed in the clay in consequence of casting with a thick slip not entirely free from air bubbles. The exterior of this pot appears perfectly sound and normal, and the existence of a serious defect would have been overlooked if an *X*-ray examination had not been made.

The practical application of the method of *X*-ray examination is very evident, even from the few examples shown here. The character of the clay itself before use particularly in regard to the presence of iron spots, may be very well studied. Further, the green pots can be examined with the view of detecting defects and unsoundness of various kinds, and, if desired or necessary, the examination can be repeated on the pots after firing if they are allowed to cool down between their initial firing and their "setting" in the furnace. Finally, pots which have behaved in an abnormal manner can be studied by this means. Nor must it be supposed that the method is unduly difficult or expensive. When the cost of a premature pot-failure or, for that matter, the premature failure of any important refractory, is considered in regard to the time lost for the furnace, the cost of installation and working of an *X*-ray outfit would be very quickly repaid by the saving of only a percentage of premature failures arising from defects.

Apart from this immediate practical utility, the method is of great importance in aiding the study of the phenomena of pot-attack on the scientific lines indicated in this lecture. While the views put forward here, and substantiated very strongly by the large amount of experimental evidence which we have obtained, indicate that pot-attack, and even strongly marked local drilling, can and do arise without the presence of local defects, yet there can be no doubt that local defects can and do cause failure of local drilling. By a preliminary X-ray examination, however, it is now possible to ascertain definitely whether any defects exist in a given experimental pot, or, at all events, to determine whether any local drilling found at the end of an experiment coincides with any previously existing defect. Evidence of this kind obviously helps very greatly to strengthen the validity of the conclusions based on experiments of the kind which have been described here.

In the account which I have endeavoured to give of certain aspects of the research work on glass which has been carried out at the National Physical Laboratory, I have laid stress rather upon the wide general principles which we have endeavoured to trace than upon any detailed practical applications. In regard to the very wide questions which we have, I believe, opened up for the first time in regard to the action of molten glass upon pots, it is very evident that much further research of a delicate and accurate nature is required, and it is our hope to carry this on in order to elucidate the many difficult points which still present themselves. I have no doubt that it is by research on these lines that the greatest advancement of our knowledge, and consequently of our industry, is to be obtained. But practical application need not await the completion or even the further development of these researches.

In order to illustrate this point, I would like to suggest one direction in which immediate practical application is not only possible, but relatively easy.

In Fig. 6 we have seen two graphs the inclination of which to one another shows the marked effect on the rate of pot-attack produced by a relatively small change of temperature. Observation on many such experiments serve to indicate that it would be a relatively simple matter to determine, for any given glass and a given pot material, a curve connecting rate of pot-attack with temperature. There is good reason to believe that the shape of such a curve would show that there is a certain range of temperature for each kind of glass above which that glass attacks the pots with undue rapidity. Having such a curve in his possession relating to his particular materials, the glassmaker would have a new and extremely valuable guide to the best working of his furnaces, knowing that the life of his pots would be rapidly endangered if a certain temperature were exceeded. He might, of course, find that for the good working of his glass he was obliged to exceed that "safe" temperature, but such a conclusion would mean that he should seek either to alter the composition of his glass or the composition or treatment of his pots until the "safe range" was raised above the temperatures required in his manufacture. This may not be possible in all cases, but there is no doubt that great improvement and economy could be effected by systematic study of the question on the lines indicated here. The experimental quantitative work required in any individual case would not be very large, and the results might easily repay the entire cost of the researches described in this lecture.

National Physical Laboratory,
Teddington, Middlesex.

XI.—*The Relations between Tridymite and Cristobalite.*

By Clarence N. Fenner.

In the Journal of the Society of Glass Technology for December, 1918 (p. 253), in an article by W. J. Rees on "Silica Refractories," the following statement appears:—

"According to Fenner, silica exists in at least seven crystalline modifications. Of these, *α-quartz* is the stable form up to 575°, *β-quartz* from 575° to 870°, *tridymite* from 870° to 1470°, and *cristobalite* above 1470°. The stability relations, particularly of *tridymite* and *cristobalite*, are, however, still in doubt, and further carefully controlled experimental work is necessary before the problem is elucidated."

In the same number of the Journal (Abst. 273, p. 169) an abstract is given of an article on the "Constitution of Silica Bricks," by Dr. Alexander Scott, which appeared in the *Transactions of the Ceramic Society*. The abstract says:—

"Evidence tends, according to the author, to confirm the idea that *tridymite* is the stable form of silica up to at least 1550°. Bricks containing about 97 per cent. of silica are practically all *tridymite* after being at this temperature for prolonged periods."

I wish to be permitted to give a brief discussion of these statements and the nature of the evidence regarding the *tridymite–cristobalite* inversion. The matter is recognised as being one of considerable practical importance to manufacturers and users of refractory materials.

Several statements of somewhat similar import, which have recently appeared, may, I think, be traced back chiefly to the evidence and conclusions submitted by H. Le Chatelier in an article contributed to the *Bulletin de la Société Française de*

*Minéralogie.** In this article M. Le Chatelier says (in translation):—

"I have assumed that at all temperatures *cristobalite* was metastable in relation to *tridymite.* But, according to the experiments of Fenner, at the Geophysical Laboratory of Washington, *tridymite* constitutes the most stable phase only up to the temperature of 1480°. Above this temperature and up to the point of fusion, at 1780°, *cristobalite* would be, on the contrary, the stable phase.

"This conclusion seems in contradiction to the fact that in steel furnaces, where the temperature is higher than 1480°, silica bricks are transformed wholly into *tridymite.* Moreover, the experiments of Fenner are open to an objection. He heated *tridymite* or *cristobalite* in the presence of a flux, tungstate of soda, and he noted, on cooling, the appearance of one or the other of the varieties of silica. At 1500°, it is seen that in the case of the heating of *tridymite* in presence of its flux, a small quantity of *cristobalite* is formed, and from that the non-stability of *tridymite* at this temperature is deduced. But there is another explanation of the same fact which is much more probable. The tungstate of soda, saturated with silica at an elevated temperature, lets *cristobalite* crystallise out on cooling, as all fluxes do. Nothing proves that this has been formed at the more elevated temperature of heating."

I think that if M. Le Chatelier had read more carefully the paper † to which he refers he would have seen clearly that considerably more evidence of the non-stability of *tridymite* above 1470° than that which he mentions is there presented, and the explanation he offers is not at all consistent with this evidence. Without dwelling upon this point, however, I wish to present here in brief form the principal evidence as to the non-stability of *tridymite* at high temperatures. Some of this evidence has been published before, but most of it appears here for the first time.

Before proceeding directly to this matter, however, I wish to point out that, because of the very remarkable properties of the forms of silica, the requirements which must be satisfied before the evidence regarding the stability of one or other form can be considered conclusive are unusually exacting. In any investigation for that purpose it may fairly be demanded that the following three requirements should be met:—

A.—There should be no doubt as to the temperature to which the sample has been exposed. The estimation of temperatures of silica-lined furnaces in industrial plants is often merely a guess, and little trust can be placed upon it. M. Le Chatelier's experience in pyrometric work has been very extensive, but not everyone who has examined silica bricks from furnaces and attempted to determine the form of silica which is stable at a given (supposed) temperature may be equally competent. Moreover, emphasis should be laid upon certain factors which are often disregarded. In nearly all furnaces operated at very high temperatures the face of the brick which is exposed directly to the highest temperature is gradually fluxed by the intense heat and the vapours and dust to which it is exposed, and that portion which is subsequently examined has been, during most of its history, buried within the mass where somewhat lower temperatures have prevailed.

---

* Vol. XL., Nos. 1—3 (January—March, 1917), pp. 44—57.

† "The Stability Relations of the Silica Minerals," *Amer. J. Sci.*, 1913, **36**, 331.

Another point should not be overlooked: few furnaces are operated continuously at the highest temperature. Generally they cool off greatly during some portion of each run. If a brick be exposed during a portion of the time to a temperature considerably above the *tridymite–cristobalite* inversion point, and during another portion of the time to a temperature considerably below this point, it would be difficult, if not impossible, to predict the response of the silica composing it to these conditions. Such considerations make it seem a very dubious procedure to draw conclusions upon stability relations from data of this nature. Laboratory work based upon temperatures which may be almost perfectly controlled by readings of carefully calibrated thermo-elements seems inherently more trustworthy and satisfactory.

B.—The methods made use of in investigation should be of such a nature that surety may be had that the allotropic form which is found is that which is stable for the given conditions. The remarkable sluggishness of the transformations between *quartz*, *tridymite*, and *cristobalite*, and the tendency shown to follow Ostwald's law of successive reactions, by which an unstable form passes through a less unstable condition in its transformation to the most stable form, tend to obscure the true relations and make it essential to use the utmost caution in drawing conclusions. Negative evidence—the fact that no change takes place—is not sufficient. Positive evidence must be found that changes do take place, and that the direction of change is reversible at will under changes of condition which are perfectly definite. The fact that *tridymite* in a dry state may be heated for a considerable period at temperatures in excess of 1470° without transformation is of no importance in drawing conclusions regarding its stability, in view of the fact that under proper conditions it may be converted into *cristobalite* (to any degree of completeness desired) at such temperatures.

C.—Methods used for distinguishing between the forms should be such that no doubt is left that a proper identification has been made. In the fine-grained condition in which *tridymite* and *cristobalite* commonly occur in silica bricks, the likeness between them is so great that identification is unusually difficult. M. Le Chatelier may have employed proper criteria for the identification of his material, but I do not find any account of them presented. The only evidence that I find given that *tridymite* persisted as such at the extreme temperature to which he exposed the material is a photograph of the product. This might represent one of these minerals or the other equally well. The most easily determinable distinctive difference between *tridymite* and *cristobalite* is the difference between their indices of refraction. When *tridymite* is immersed in a liquid of index 1·475, tests by the half-shade method or by the Becke-line method show that the index of the material is so nearly matched that the difference is scarcely appreciable. A similar test may be used for *cristobalite,* using a liquid of index 1·485. When both are present, a liquid of index 1·480 will serve to show the proportions. In making up immersion liquids for use in this manner, a solution of potassium–mercury iodide, which is sometimes recommended, is not at all suitable, because of the change in index which is likely to occur while it is being used. It is much better to make use of mixtures of albolene,* the index of which ranges from 1·477 to 1·485, with kerosene ($n = 1{\cdot}450 \pm$) or with α-monobromonaphthalene ($n = 1{\cdot}658$).

Other distinctive differences between *tridymite* and *cristobalite* are that *tridymite* frequently assumes a lath-like development, and extinction is then strictly parallel to the elongation, which is α. Wedge-shaped twins are common. With *cristobalite,* the grains are frequently elongated (perhaps an inherited property), but extinction may occur at various angles. A quite noticeable characteristic of *cristobalite* is polysynthetic twinning, which gives several narrow stripes, as in *plagioclase felspar,* or the twinning may resemble the plaid effect of *microcline.* A method of discrimination between *tridymite* and *cristobalite,* of great value, depends upon the different temperatures of the α-β-inversions. This, however, requires the use of special apparatus.

Let us pass now to the evidence regarding the specific points under consideration. I will give first the results of some of my own experiments.

---

* A petroleum product; "Russian oil," "American oil," and so forth, are practically the same.

Experiment 112.—A mixture of finely ground, specially purified *quartz* (44·5 grams) and crystallised tungstate of soda (14·8 grams) was heated for 118 hours at 1000° ±.* The resulting material was washed, broken up, and treated in succession with HCl, NH_4OH, and hot water. The product was practically pure *tridymite*. The index did not differ sensibly from 1·475, and the other optical properties were in agreement. Moreover, the α-, β_1-, β_2-inversion temperatures were determined and found to be 117·7° and 162·4°, agreeing perfectly with *tridymite*. Chemical analysis of this material showed 0·51 per cent. impurity, probably mostly tungstic acid. Many similar results on the transformation of *quartz* into *tridymite* at temperatures up to 1470° were obtained in other experiments.

Experiment 168.—*Tridymite* from experiment 112 was ground rather fine in an agate mortar and placed in a platinum crucible *without flux*. It was heated in a platinum resistance furnace as follows:—

1.20 p.m.	1423°	2.02 p.m.	1580°
1.42 ,,	1523	2.02—3.55 p.m	1585

The *tridymite* was converted entirely into *cristobalite*. The index was found to have been raised to 1·485, and in many grains the characteristic polysynthetic twinning was prominent. Extinction was not parallel to elongation. A determination of the α-β-inversion temperature was made, and it was found to be 268·3° on heating and 238·2° on cooling. All the properties agreed perfectly with those of *cristobalite*. Attention should be paid to the fact that no flux was used, so that no supposed influence can be ascribed to that agent.

In the experiment just described, a temperature of 1580° was found to cause complete inversion of *tridymite* to *cristobalite* in the dry way in about two hours. Since in the abstract of Dr. Scott's paper, quoted at the beginning of this article, it is held that *tridymite* is the stable form up to at least 1550°, the following experiment is of interest.

Experiment 199.—*Tridymite* powder from experiment 112 was placed in a thimble crucible suspended just below the thermo-element in an electric furnace. It was heated as follows:—

11.25 a.m.	1523°	3.13 p.m.	1542°
12.05 p.m.	1556	3.38 ,,	1552
1.20 ,,	1560		

The sample, when removed and examined, was found to be approximately half *cristobalite*. The *cristobalite* portion gave an index very noticeably greater than 1·475 or 1·480, and apparently equal to 1·485. It showed the characteristic polysynthetic twinning with inclined extinction or plaid effect. The sample was replaced in the furnace and heated again:—

---

* For the purposes of this experiment an approximately constant temperature was all that was required.

11.58 a.m.	1366°	3.05 p.m.	1556°
1.00 p.m.	1544	4.30 ,,	Heating current shut off.

Examination of the material showed that approximately three-fourths of it had been converted into *cristobalite*. These results seem incompatible with the interpretations given by Le Chatelier, Rees, and Scott.

In these experiments, a flux was found to be unnecessary to convert *tridymite* into *cristobalite* at the temperatures stated. With much decrease of temperature, the transformation proceeds much more slowly; therefore in the determination of the exact temperature of inversion a material was added to hasten operations. For this purpose, tungstate of soda was used. According to M. Le Chatelier, the *cristobalite* obtained under such conditions was simply that which was taken into solution at a high temperature and crystallised out on cooling. Such a process is perfectly conceivable, but the objection is that, according to the evidence, things do not work in that fashion. Probably the reason is that the amount of silica which goes into solution *as such* in the flux is so small that it is imperceptible. It is true that at high temperatures (1400° and above) prolonged heating of silica in contact with large quantities of tungstate of soda effects some sort of solution of silica, such that a hard glass results, but this is probably a reaction product (possibly a silico-tungstate). At any rate, this glass is a most intractable material, and when it has been produced nothing further seems to happen, so that efforts were made to avoid it. This was effected by using only small quantities of tungstate at these high temperatures, so small that the melted tungstate merely moistened the mass of *tridymite* grains. If silica were taken up by the tungstate liquid and re-deposited on cooling (as M. Le Chatelier has supposed), there is no reason why this process should cease at temperatures below 1470°; but it is only above this temperature that *cristobalite* can be discovered when *tridymite* is heated with tungstate. Moreover, at temperatures above 1470°, the amount of *cristobalite* increases with length of heating.

Experiment 203.—In a crucible about 16 mm. in height a little sodium tungstate was melted—enough to form a layer 1—2 mm. in depth. The crucible was then filled with pure *tridymite*, prepared in a manner similar to that described under experiment 112.

The crucible was hung just beneath a thermo-element, and heated as follows:—

9.25 a.m.	1224°	2.14 p.m.	1520°	
10.35 ,,	1473	3.19 ,,	1537	
11.16 ,,	1498	4.05 ,,	1537	Crucible removed.
12.02 p.m.	1514			

The product was leached with HCl, NH_4OH, and H_2O. Microscopic examination showed that it had been converted completely into *cristobalite*. The index was 1·485, and the characteristic polysynthetic twinning was very evident.

Experiment 202.—*Tridymite* was first prepared by heating quartz with a considerable quantity of sodium tungstate at 1000—1100° for several days. This effected complete transformation into *tridymite*. Some of this material, with its excess tungstate, was crushed to pass 100 mesh and placed in another crucible which had a small crack in the bottom to permit the excess of melted flux to drain off. It was heated as follows[*]:—

11.12 a.m.	1506°	1.15 p.m.	1493°	
12·03 p.m.	1531	2.00 ,,	1473	Crucible withdrawn.

Examination of the leached material showed that it had been completely converted into *cristobalite*. The optical properties were such as to leave no doubt.

Experiment 100.—Artificial *tridymite*, prepared by heating finely ground *quartz* to 1000° ± for seventy-six hours, was mixed with a little sodium tungstate and heated with careful regulation, as follows[†]:—

February 2,	1480°	for five hours
February 3,	1480 ,,	four and a-half hours
February 5,	1480 ,,	five hours twenty minutes except that for a short period the temperature dropped to 1468°.

The total heating was fourteen hours fifty minutes. Much of the *tridymite* had been converted into *cristobalite*. The proportions were approximately one-third *cristobalite* and two-thirds *tridymite*.

Confirmation of these relations was obtained by the following experiment:—

Experiment 113.—*Cristobalite* was made by heating amorphous silica with sodium tungstate (in the proportion of 3·87 to 1) to

---

[*] In this case the thermo-element was some distance from the crucible, so that the temperature-readings may not apply exactly. For the purpose in view this is not of great importance.

[†] The heating was done in three periods simply to avoid the possibility that in leaving the experiment unwatched overnight the temperature might vary.

1570° ± for four and a-quarter hours. To this material (washed) a little tungstate was again added, and the mixture heated (with two interruptions) for twelve hours thirty-five minutes at 1480°. The product was entirely *cristobalite* with unchanged characteristics.

As evidence of the fact that below 1470° (the inversion point) different results were obtained, the following experiment is pertinent:—

Experiment 114.—*Cristobalite* from the same preparation as was used in experiment 113 was mixed with a little sodium tungstate and heated to 1460° for four and three-quarter hours. The product was mostly *cristobalite*, but there were numerous grains of *tridymite* having an index of 1·475 and characteristic, wedge-like twinning or in parallel-extinguishing, lath-like forms.

The experiments by which a temperature of 1470 ± 10° was finally decided upon as that of the inversion point are described in the paper on the "Stability Relations of the Silica Minerals," and it is not necessary to repeat the description here.

At temperatures much below the inversion point, the transformation from *cristobalite* to *tridymite* proceeds with reasonable rapidity. The following experiment is cited in confirmation of this.

Experiment 205.—Ground *quartz* was first converted into *cristobalite* by heating it without a flux in a Fletcher gas furnace to near the fusing point. Conversion was apparently complete. A determination of the α-β-inversion temperatures gave 254·0° on heating and 224·3° on cooling. This *cristobalite* was mixed with crystallised tungstate of soda in the proportions 5:1, and ground in an agate mortar. The mixture was placed in a thimble crucible suspended from a thermo-element, and heated as follows:—

11.16 a.m.	1399°	3.37 p.m.	1382°
12.27 p.m.	1407	4.15 ,,	1382

The mixture was removed from the furnace and treated with HCl, NH_4OH, and H_2O. Microscopic examination showed plainly that most of the material had been converted into *tridymite*, as evinced by the optical characteristics.

The results which have been obtained by heating *quartz* with sodium tungstate at temperatures above and below 1470 ± 10° confirm the relations. To show the procedure followed and the sort of evidence obtained, the following two experiments are described:—

Experiment 111.—Finely ground, specially purified *quartz* was well mixed with crystallised sodium tungstate in the proportion of

3 to 1. The mixture was heated to 1570°±. for five and a-half hours. The resulting material was thoroughly treated with HCl, NH_4·OH, and hot water. Under the microscope, the index was found to be sensibly equal to 1·485, and polysynthetic twinning was abundant. A determination of the α-β-inversion gave temperatures of 274·6° on heating and 238·1° on cooling. These properties are in complete accord with those of *cristobalite.* A determination of the residue left after treatment with hydrofluoric acid gave 0·32 per cent.

Experiment 144.—Ground *quartz* was mixed with sodium tungstate and heated as follows:—

10.40 a.m.	1250°	12.46 p.m.	1308°	
11.54 ,,	1294	2.00 ,,	1298	Crucible removed.

The washed material had the characteristic optical properties of *tridymite*, and apparently consisted wholly of this mineral. Determination of the α-, β_1-, β_2-inversion temperatures gave 117·3° and 165·2°.

These experiments are typical of many others which might be cited. In the course of a long series of experiments, no obvious loophole was left by which one could escape the conclusions regarding the stability relations which have been drawn. At temperatures above 1470±10°, *quartz*, *tridymite*, and amorphous silica have repeatedly and unequivocally been converted into *cristobalite*; between 1470±10° and 870±10°, *quartz*, *cristobalite*, and amorphous silica have similarly been converted into *tridymite*; and below 870±10°, *tridymite*, *cristobalite*, and amorphous silica have been converted into *quartz*. These relations have been confirmed again and again. Moreover, recent work by Ferguson and Merwin* has indicated that the melting point of *tridymite* is considerably lower than that of *cristobalite*. It follows necessarily from this observation that *cristobalite* is the high-temperature form.

In spite of the apparent clearness of the evidence, I wish to avoid a stand which may appear dogmatic, and if anyone is able to bring forth what appears to him to be good experimental evidence of the incorrectness of the conclusions I have drawn, I shall be glad of an opportunity to repeat such experiments.†

It may be mentioned in passing that M. Le Chatelier's figure of 1780° as the fusion point of *cristobalite* seems to be considerably too high. This may be easily demonstrated, for *cristobalite* may be fused completely to a glass in a platinum crucible in a Fletcher gas furnace. In making this experiment, the platinum container should be set within a porcelain crucible in order to avoid direct impingement of the flame on the platinum and to secure a more uniform distribution of temperature. Since the fusing point of platinum is 1755°, and since the *cristobalite* may be completely melted without evidence of any effect on the platinum, the fusing point of *cristobalite* is necessarily below 1755°. The most trustworthy determination thus far made seems to be that of Ferguson and Merwin,* who placed the melting point at 1710 ± 10°.

---

* J. B. Ferguson and H. E. Merwin, "The Melting Points of Cristobalite and Tridymite," *Amer. J. Sci.*, 1918, **46**, 417.

† Extended experiments on silica by J. B. Ferguson and H. E. Merwin, in connection with their work on the system CaO–MgO–SiO_2, to be published within the next few months, are in complete accord with the data already quoted.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D.C.

April, 1919.

XII.—*The Annealing Temperatures of the Lime-Soda Glasses.*

By S. English, M.Sc., and W. E. S. Turner, D.Sc.

(*Read at the Leeds Meeting, November 20th*, 1918.)

Concerning the variation of the annealing temperature with the composition of the glass, only the main outlines are as yet known. Practical experience has laid down the rules that lead glasses are readily annealed, whilst chemical glassware, on the other hand, requires a high annealing temperature followed by slow rate of cooling if strain is to be first removed and then prevented from recurring.

The actual data for certain general classes of glassware, including lead glasses, lime glasses, boric oxide-containing, and chemical glassware, have been determined previously by us and discussed in a previous number.† So far as we can ascertain, however, no scientific worker has yet made an attempt to study the effect of the variation of composition in any one of these types and thus ascertain clearly what is the effect of the presence of a definite constituent. The results now described, therefore, open out a new field, whilst the information is of importance in view of the fact that the lime-soda series of glasses is of the greatest commercial importance, and since the proportion of lime used for different types of glassware may vary considerably, it is very desirable to set down the proper conditions for their treatment in the lehr.

---

* Ferguson and Merwin, *op. cit.*

† This Journal, T., 1918, **2**, 90.

The series of lime-soda glasses which has been investigated represents a very considerable variation in the proportions of soda and of lime, and includes the more important commercial glasses. In addition to the series in which the proportion of silica was kept constant (glasses 1—11), two other glasses, numbered here 16 and 17, were studied, both of them being commercial glasses used for common bottles.

The glasses were all specially prepared in the Department, for the purpose of the research, either in 28 lb. or 56 lb. melts. The description of the glasses and their preparation can best and most adequately be dealt with in a separate paper, which it is hoped will appear, together with other papers dealing with their properties, in the next number of the Journal. For the purpose of this paper, however, it is sufficient to quote the compositions of the glasses (table I):—

TABLE I.

Glass.	SiO_2.	Na_2O.	CaO.	MgO.	Al_2O_3.	Fe_2O_3 ~~Fe_2O_4.~~	As_2O_3 ~~As_2O_4.~~	Total.
1	74·05	25·34	0·21	trace	0·24	0·14	—	99·98
2	73·92	23·80	1·50	trace	0·20	0·14	—	99·56
3	74·08	23·00	2·61	trace	0·21	0·15	—	100·05
4	74·07	21·50	3·81	trace	0·28	0·14	—	99·80
5	73·78	20·78	4·50	0·15	0·38	0·19	—	99·78
6	73·18	19·38	6·26	0·21	0·58	0·61	—	100·22
7	74·41	17·20	7·45	0·24	0·30	0·40	—	100·00
8	74·99	16·00	8·16	0·26	0·31	0·09	—	99·81
9	74·96	14·88	9·36	0·28	0·42	0·16	—	100·08
10	74·59	14·22	10·38	0·30	0·45	0·21	—	100·15
11	74·93	13·02	11·68	0·31	0·38	0·17	—	100·49
16	66·71	12·72	18·17	0·85	1·41	0·31	0·30	100·47
17	69·73	11·22	17·38	0·55	0·50	0·25	0·47	100·10

In the previous paper it has been pointed out that the complete determination of the annealing conditions for any glass involves (1) the measurement of the upper annealing temperature, or the temperature at which annealing occurs most readily without deformation, (2) the determination of the lower annealing temperature (below which annealed glass can be cooled rapidly without strain), and (3) the rate of cooling between these two values.

Whilst a good deal of work has already been done towards (2) and (3), these sections involve still further study, and in order that results of value may be presented without delay, the variation of the upper annealing temperature is discussed here.

The method involved was the optical method already described at length in the previous paper. Short glass rods, 3 cm. long and 8 mm. in diameter, with plane polished ends, were employed. Different specimens were not all strained to the same extent when inserted in the heating furnace, some showing one ring and cross, some two rings, but the rate of disappearance of the rings near the upper annealing temperature is so rapid that small initial differences are without material effect on the determination.

The results are tabulated below. Each annealing temperature is the mean of two determinations:—

Glass No.	Percentage of lime (CaO).	Annealing temperature.
1	0·21	483°
2	1·50	490
3	2·61	492
4	3·81	503
5	4·50	512
6	6·26	526
7	7·45	538
8	8·16	552°
9	9·36	562
10	10·38	581
11	11·68	601
16	13·17	608
17	17·38	613

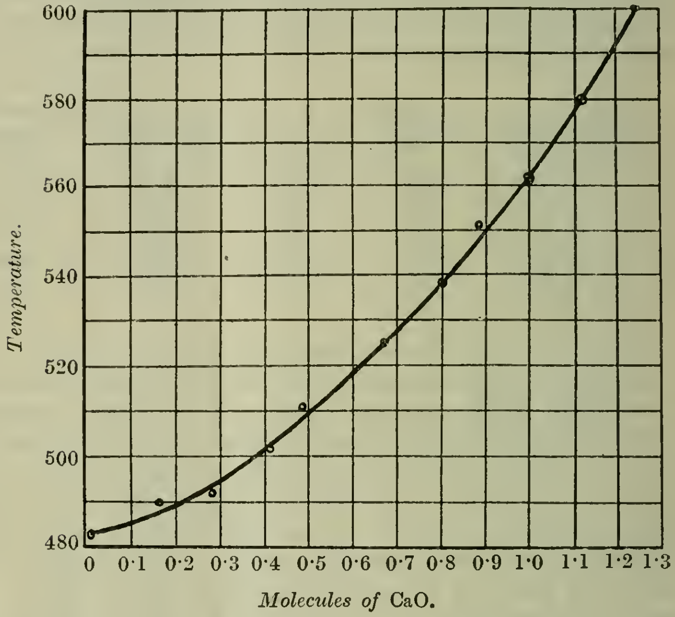
The diagram (p. 128) which summarises the results has been drawn up by plotting the molecular content of the lime (CaO), calculated from the results of the analyses, against the annealing temperature. It will be seen that the various values all lie on or near a smooth curve which rises fairly steeply, increasingly so in the higher part of the series. The values for the glasses Nos. 16 and 17 are not included in this curve, since they belong to quite other series containing different proportions of silica. For glasses 1—11 the amount of silica will be seen to be practically constant.

The results of the experiments, therefore, show that glasses with a high proportion of alkali can be annealed at a fairly low temperature. Although requiring a higher temperature than lead glasses, they nevertheless resemble the latter in that both soften comparatively readily. With substitution of the alkali by lime, however, the glass hardens, whilst its annealing temperature ascends. The bottle glasses, Nos. 16 and 17, with highest proportions of lime, have highest annealing temperatures, approaching those of chemical glass. High lime content is by no means uncommon in the manufacture of common bottles, especially by hand processes.

In practice, ordinary white flint (lime-soda) glass for medical bottles, paste, sauce, and pomade bottles, etc., have a composition which usually lies between that of glasses 7 and 9. With the automatic feed devices, also, such glass is usually employed. Hence the temperature of the lehr should be regulated accordingly.

In conclusion, the object of this paper is to demonstrate that different soda-lime glasses cannot be treated alike in the lehr, and if the batch composition is altered, so also must the heat applied to bring about effective annealing. Thus glass 16 requires that the lehr should be maintained at a temperature 56° C. or 89° F. higher than when required to anneal glass 8. As it has previously been shown that an alteration of 5° in the neighbourhood of the annealing temperature has a very great influence on the speed of annealing, proper adjustment of the lehr to the glass is important.

Variation of annealing temperature with lime content.



In the above series of glasses, the only substances present other than lime, soda, and silica are small quantities of alumina and iron, and magnesia derived either from the raw materials or from the pots. In commercial lime-soda glasses, the amounts, notably of alumina and magnesia, may be considerably greater and may modify the annealing temperatures stated. It will be the object of subsequent papers to demonstrate the effect which such constituents exert.

Department of Glass Technology,
The University, Sheffield.

XIII.—*Further Investigations on Chemical Glassware.*

By Constance M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

In a former paper,[*] reference was made to the fact that no examination had been made of two types of American glassware, namely, that of the Macbeth Evans Glass Co. and of the Libbey Glass Co., although P. H. Walker and F. W. Smither had tested them.[†]

More recently, the former type has come into our possession, and through the courtesy of the Macbeth Evans Co. we are enabled to publish the results of the investigation.

The glass was analysed and found to have the following percentage composition:—

SiO_2	71·03
Al_2O_3	1·57
Fe_2O_3	0·35
CaO	0·64
MgO	2·61
ZnO	5·30
Na_2O	10·74
K_2O	0·30
B_2O_3	7·44
As_2O_3	0·05
Sb_2O_3	0·45
MnO	trace
	100·48

In one or two respects this composition differs from that of the specimens examined by Walker and Smither. Thus, in our specimen, the silica is 2 per cent. lower and the magnesia 1·7 per cent. lower, whilst, on the other hand, the boric oxide is 3·8 per cent. higher.

The tests which have been carried out on the sample follow precisely the lines described in the paper by Cauwood and Turner,[‡] and a reference to that paper will provide the reader with all experimental details. Duplicate tests were carried out, and in most cases the glass was subjected to the action of the reagent for three successive periods of time.

---

[*] "The Resistant Properties of some Types of Foreign Chemical Glassware," Cauwood and Turner, this Journal, 1918, Trans., 2, 219.

[†] *J. Ind. Eng. Chem.*, 1917, 9, 1090. This Journal, Abs. 1918, No. 14.

[‡] *Loc. cit.*

I. *Action of Boiling and Evaporating Water.*

300 c.c. of water were boiled down to 100 c.c. in two hours.

Flask.	Area exposed to mean volume. sq. cm.	Periods of treatment.	Total loss in weight. mg.	Alkali extracted. mg. Na_2O.
I	135	1	0·4	0·05
		2	0·4	0·05
		3	0·4	0·05
II	135	1	0·5	0·06
		2	0·4	0·05
		3	0·4	0·05

II. *Action of Water and Steam at* 183° *and Pressure of* 10 *kg./sq. cm.*

250 c.c. of conductivity water were added to the flasks. The area exposed to water was 155 sq. cm., to steam 689 sq. cm.

Flask.	Total loss in weight in mg.	Total alkali extracted. mg. Na_2O.
I	69·0	8·7
II	74·4	10·5

After treatment, the water in the flasks contained flakes derived from the glass, whilst distinct etching occurred at the water-level as well as slight etching below and slight staining above.

III. *The Action of* 2*N*-NaOH *for Three Hours at* 100°.

150 c.c. of the caustic alkali solution were used, the area covered by the reagent being 112 sq. cm.

Period of treatment.	Loss in weigh in mg. per sq. dcm. Flask I.	Flask II.
1	84·8	83·9
2	83·0	81·2
3	81·2	80·3
Total	249·0	245·4

The residual solution contained flakes, whilst the flasks were etched below the liquid-level and stained above.

IV. *The Action of N*/10-NaOH *for Three Hours at* 100°.

150 c.c. of solution were used. Area exposed, 112 sq. cm.

Period of treatment.	Loss in weight in mg. per sq. dcm. Flask I.	Flask II.
1	20·5	19·6
2	18·7	17·8
3	17·8	16·9
Total	57·0	54·3

Small flakes were present in the liquid after treatment, and slight staining occurred above the liquid-level.

V. *The Action of* $2N$-Na_2CO_3 *at* 100°.

150 c.c. of sodium carbonate solution were employed. Area exposed, 112 sq. cm.

Period of treatment.		Loss in weight in mg. per sq. dcm. Flask I.	Loss in weight in mg. per sq. dcm. Flask II.
1		30·9	29·4
2		29·8	28·5
3		28·5	27·6
	Total	89·2	85·5

VI. *The Action of Boiling* 20·24 *per cent. Hydrochloric Acid for One and a-half Hours.*

250 c.c. of the acid were evaporated to 100 c.c. in the time stated. Area covered by the mean volume, 125 sq. cm.

Period of treatment.		Loss in weight in mg. per sq. dcm. Flask I.	Loss in weight in mg. per sq. dcm. Flask II.
1		0·8	0·9
2		0·6	0·6
3		0·2	0·2
	Total	1·6	1·7

In previous papers from the laboratory, an attempt has been made to classify the different types of ware as Good, Moderate, and Bad. Measured by the total losses in weight suffered, the extreme variations previously found in the class labelled "Good" were:

Boiling water.	Auto-clave.	$2N$-NaOH.	$N/10$-NaOH	$2N$-Na_2CO_3.	Boiling HCl.
0·5—1·4	15·4—85·9	235·8—312·5	41·0—65·4	74·1—96·8	0·7—9·7

Except in the case of the boiling water and the autoclave tests, the values are the totals for three periods of test.

When the results of the tests on the Macbeth Evans glass are compared with the above limits, it will be seen that for every reagent tested the glass easily falls within the first class, so that the authors' tests have revealed now seven glasses which are good all round. The composition, it will be noted, is that of a zinc–borosilicate. Alumina is present only to a small extent, and is therefore, in this case, not the component which imparts resistance.

Department of Glass Technology,
The University, Sheffield.

XIV.—*The Year's Progress in Glass Research under the Auspices of the Glass Research Delegacy.*

By W. E. S. TURNER.

THE year to which this report refers was that which ended on March 31st, 1919, the official end of the session of the Delegacy, and the record is therefore a little belated.

To a very large extent the reports of the Delegacy and of its several Committees speak for themselves, and tell the story of the work done as well as that in hand and of the anxiety continually felt in regard to financing it.

There is one special section, however, which may bear some further comment, namely, the degree course which has been set up now that once again students have returned to the University.

In a subject of applied science, there is perhaps as yet no certainty as to the best method of training students. It has been customary, hitherto, to pursue a course in which the student spends three years continuously in his University studies, gaining in this way a sound knowledge of theory, but having to be content with such practical knowledge as can be acquired in laboratories and by visits to works. There is something to be said for teaching a student as much as possible of the theories of science during his University career. He seldom has time or opportunity later on, and on passing out into works practice he speedily finds where his theoretical knowledge will stand him in good stead, whilst the practical experience he gradually acquires gives him confidence in jettisoning all useless or erroneous theory.

There are some who hold, however, that an applied science subject ought to be taught from the outset to the accompaniment of operations entirely practical. But no institution, however elaborate its equipment, can hope to afford commercial working conditions; it can only deal with principles. For this real practical training it is necessary to look to the factory to co-operate with the University.

An attempt is now being made to provide both types of course, and it may be possible later on to arrive at a conclusion as to their respective merits. The three years' course referred to is the one following well-known University practice. The four years' course is new. A student who enters for it is enabled to spend six months of the year at a glass factory and six months at the University. Apart from the extended opportunity of acquiring practical knowledge before graduation, the arrangement has at least this advantage, that it makes it possible for an ambitious young man to earn sufficient money to maintain himself during a period of University training.

In order that the new scheme may be workable, it is essential that the support of manufacturers shall be gained. Already one firm has offered to receive students, and the writer would be glad to hear from other manufacturers of their willingness to co-operate in this work.

THIRD ANNUAL REPORT OF THE DELEGACY FOR GLASS RESEARCH.

During the year there has been no considerable extension of the equipment, but mention may be made of the installation, at last, of an adequate compressor delivering nearly 23,000 cubic feet per hour, and making it possible to work all the furnaces simultaneously, still leaving a good margin. Some wire-wound electric tube furnaces have been made in the department capable of reaching temperatures exceeding 1500°, and are doing very useful work in the researches on refractory materials. Further, a special set of dust-proof bins, of acid-proof stoneware set in wooden chambers, for the preservation of glass-making materials, and another set without stoneware linings, for clay storage, have been erected.

The gas furnaces worked with compressed air have continued to give service, but experience has shown it highly desirable to consider the erection of a natural draught furnace in order to increase the life of the pots, and before the end of the year such a natural draught furnace will probably be in operation.

The Delegacy has had the pleasure of welcoming to its strength two representatives of the Worshipful Company of Glaziers, namely, Sir Harry Seymour Foster, Bart., and Mr. P. W. Berriman Tippetts, D.L., J.P. During September, 1918, the Company entertained members of the Delegacy, with other representatives of the glass industry, to lunch, after which an address was given by Dr. Turner. The Worshipful Master, Mr. Paget Walford, expressed the desire of the Company to assist in the work of the Delegacy.

During the year, also, the Delegacy had the pleasure of welcoming a deputation from the Department of Scientific and Industrial Research, when the Department at Sheffield was thoroughly inspected and the opportunity was taken for a frank and helpful exchange of views.

In the early part of the present year it became necessary, owing to the great influx of students into the Chemistry Department, to give up the space which was allotted to the Glass Department during the years of war. Accommodation had to be found for the teaching work and for the chemical research work and office work, and this proved no easy matter. It was eventually solved through the good offices of the Vice-Chancellor, Dr. Ripper, who placed a laboratory and classroom in the Engineering Department at the disposal of the Glass Department. The thanks of the Delegacy are due also to Prof. Wynne for finding accommodation for certain sections of the Department during its initial years.

The laboratory and lecture-rooms provided in the Engineering Department can only be made available temporarily. Moreover, the laboratory is quite inadequate to carry on research work with comfort, and was never equipped for such a purpose. It is also too small to house the students expected at the beginning of the new session.

The question of accommodation has been one for serious consideration by the Delegacy, and has been raised at each meeting. At the present time, the work of the Department is scattered, some in the Physical Chemistry Laboratory of the Chemistry Department, some in the Physics Department, Western Bank, the teaching work and chemical testing at St. George's Square and the rest at Badger Lane. A special Committee set up by the Delegacy gave consideration and approval to two Memoranda last December, one dealing with the future work of the Department, the other with the extended accommodation urgently needed.

There are two serious difficulties in the way of extension. The first is the difficulty of building and of ejecting tenants from houses on the site needed; the second is the financial difficulty. Assistance towards building, it has been hoped, would be forthcoming from two sources in particular, namely, the Board of Education through special grants, and the glass manufacturers. The former has, unfortunately, not been able to assist. In the case of the manufacturers, the new Glass Research Association, which is in course of formation, and for which an appeal is being made to manufacturers, would seem to preclude a further appeal for funds for building purposes. It is the earnest hope of the Delegacy that the glass manufacturers will come forward with offers of substantial assistance in what threatens to be an impasse.

The maintenance fund presents less difficulty, although the work to be done increases very much faster than the income. The Delegacy has much pleasure in acknowledging the continued support of the West Riding County Council, the Association of Glass Bottle Manufacturers of Great Britain and Ireland, and the

British Laboratory Ware Association, whilst it is much encouraged by the generous support of the Yorkshire Glass Bottle Manufacturers Association and the Yorkshire Flint Glass Manufacturers Association, each of which has agreed to subscribe £250, which it is hoped will be an annual contribution. It is also hoped that other associations will follow the lead of those now contributing so as to give the Delegacy an assured income

Meanwhile, the demands on the Department increase, and, despite drawbacks due to accommodation, work does get done. The Society of Glass Technology has requested the Delegacy to undertake a series of investigations on glass refractories, and it has been necessary to appoint additional staff in the persons of Mr. F. W. Hodkin, B.Sc., and Miss E. M. Firth, B.Sc., whilst Miss V. Dimbleby, B.Sc., was appointed owing to the considerable increase in other research work. At the end of March, therefore, the research staff, in addition to Dr. Turner, numbered eight.

As in other reports, details of the work may be summarised under the following headings:—

I.

Systematic Research Work.

A good deal is in progress, as will be evident from the following list and the reports of the committees. The following papers have been published during the year:—

"A Simple and Accurate Method of Rapidly and Accurately Calibrating Pipettes," by S. English, M.Sc.

"The Resistant Properties of some Types of Foreign Chemical Glassware," by J. D. Cauwood, M.Sc., and W. E. S. Turner, D.Sc.

"The Effect of the Continued Action on Chemical Glassware of Water, Acid, and Alkali," by J. D. Cauwood, M.Sc., and W. E. S. Turner, D.Sc.

"Note on the Determination of Boric Oxide in Glass," by J. D. Cauwood, M.Sc., and T. E. Wilson, B.Sc.

"The Effect of Temperature on the Rate of Corrosion of Glass," by J. D. Cauwood, M.Sc., and W. E. S. Turner, D.Sc.

"Note on the Solubility of Clay in Glass," by J. H. Davidson, M.Sc., and W. E. S. Turner, D.Sc.

"The Rapid Calibration of Burette Tubes," by S. English, M.Sc.

"Bottle Glass and Glass Bottle Manufacture," by W. E. S. Turner, D.Sc.

In addition to the above, five other papers were communicated during the year to the Society of Chemical Industry or the Society of Glass Technology, and now await publication.

II.

Work for Manufacturers and Others.

This side of the Department's activities is increasing to a marked degree. The laboratories are being used more and more as a central testing station for the raw materials of glass manufacture, whilst furnace tests are greatly increasing in number. It may be desirable to develop a special branch of the Department in order to discharge this work and not interfere with systematic research work.

During the year, 151 cases of inquiry have been dealt with. Classified, they are:—

1. Inquiries and consultations involving no experimental work	80
2. Examination of raw materials and the investigation of problems arising during the manufacture of glass ...	58
3. Determinations of the physical properties of glass ...	13

III.

Educational Work.

The influence of the War on educational work reached its culminating point during this past year, and the Armistice came too late to permit any marked revival of classes in the session 1919—1920.

Nevertheless, four students at various times between October, 1918, and March, 1919, were welcomed back from military duties and took up the Degree and Diploma Courses.

The Local Centre Courses were carried on, and, despite smaller numbers, some very keen and capable students have been discovered. About sixty were enrolled in the classes conducted at Barnsley, Derby, Leeds, Mexborough, and Sheffield, more than half this number attending at Sheffield. A particularly pleasing feature of these classes is the fact that the previous year's successful Final students attended for a further special course, and intimated their intention of continuing in further years so long as their work permits.

It is with great regret that the Delegacy has learned of the death of the manager of Messrs. P. Waddington and Sons, Mexborough, Mr. J. H. Crowther, through whose help and influence the first class at Mexborough was begun and continued with great enthusiasm.

It has not been possible to continue the systematic lecture courses for lampworking students owing to the fact that almost all incoming students now are disabled soldiers who enter as vacancies occur, and never in sufficient number at any time to form a class.

An evening class in lampworking was held, and twenty students were registered.

REPORT OF THE BOARD OF MANAGEMENT OF THE LAMPWORKING SCHOOL.

During the past year, the School has accepted for training twenty-two discharged and disabled soldiers, whilst in the same period eight girls and one boy have taken various courses of training. All the discharged soldiers have not proved suitable, but throughout the year the whole of the accommodation of the School has been taken up, whilst there are ten disabled men on the list for vacancies to occur so that they might be accepted for training.

The best method of determining the suitability of these men, and the one that has been adopted, is to accept those whose medical certificates are satisfactory for a probationary period of one month. The War Pensions Committee concerned is then communicated with as to the advisability for continuance of training or for withdrawal from the School, as the case may be.

Ten discharged men and four girls who have completed courses of training have been placed with manufacturers, and reports of their progress have been completely satisfactory. Generally the men have taken up the making of general scientific apparatus, but two have been employed by a Manchester firm for making artificial eyes, and they are now doing the simpler kinds quite satisfactorily. Three women have been sent by firms for special courses dealing with some particular branch of medical glassware. One discharged soldier was sent by a firm of manufacturers for a short course in calibrating and graduating.

At the British Scientific Products Exhibitions in London (August 12th—September 7th, 1918) and in Manchester (December 31st, 1918—January 10th, 1919), some of the articles made in the School were exhibited on the stalls allotted to the Department, and aroused interest. Recently at the Discharged Soldiers Exhibitions held in Sheffield (May 15th—31st), the School's exhibit, together with a continuous demonstration by six of the men, proved to be one of the most attractive features of the exhibition.

During the winter, an evening class in lampworking for scientific workers in laboratories was held. The number of pupils who registered was twenty.

The services of the School have also been called on in the supply of several pieces of research apparatus, whilst at the request of other university departments and of Sheffield steel firms, the checking of graduated apparatus, for which the School is well equipped, has been carried out.

The research work carried on and finished during the year has been a continuation and development of some of the subjects mentioned in the last report. The volumetric method of calibrating pipettes has been developed and applied to cylinders, flasks, and burettes. A complete apparatus for the exact calibration of burettes, using this principle, has been described. The small machine for making fountain-pen fillers has been developed, and as a result a semi-automatic machine for making specimen tubes and test-tubes has been evolved.

Research work in progress at the present time includes a study of

(*a*) Glass-grinding materials,
(*b*) Etching reagents,

and the construction of a direct-reading gas analysis apparatus.

W. E. S. Turner (*Chairman*).
S. English (*Secretary*).

APPENDIX.

Schedule I.

Return of Number of Pupils in the School during the Year 1918—1919.

No. of pupils in School on June 1st, 1918	18
No. of pupils registered during the year	24
No. of pupils in School on June 1st, 1919	20
No. of discharged soldiers not retained more than one month	6
No. placed in new positions	10
No. returned to employers	6
No. on waiting list	10

REPORT OF THE COMMITTEE ON POT FURNACE WORKS PROBLEMS.

The Committee has held two further meetings since issuing the last report to the Delegacy, namely, on December 11th, 1918, and June 12th, 1919.

Much work has been under consideration by the Committee and brought before the Department for the purpose of research.

I. In connection with the research programme drawn up in May, 1918, and subsequently extended, the Committee has to report that the following, amongst the larger problems under consideration, have been investigated and the work brought to a conclusion:—

1. The solubility of pot material in glass.
2. The annealing temperatures of soda-lime glasses.
3. The use of arsenious sulphide as a flux in glass making.
4. The resistance of soda-lime glasses to water and other reagents.
5. The densities of the lime-soda glasses.
6. The thermal expansions of soda-lime glasses.
7. The elasticity of the lime-soda series of glasses.
8. The effect of lime on the refractive index of glass.
9. The production of opal lampworking tubing suitable for the manufacture of artificial eyes.
10. The production of flat polished plates of glass opaque to visible, and transparent to ultra-violet, light.
11. The suitability of an alumina waste product for use as a glass-making material.

II. In addition to the foregoing, a considerable amount of work has been carried out on the following problems:—

1. The crushing strength of the soda-lime glasses.
2. The effect of alumina on glass.
3. The most efficient rate of cooling glass to prevent strain.
4. The attack by glass on the refractory materials used in the glass industry.
5. The determination of the effect of magnesia on the properties of glass.
6. The production of coloured glasses for the manufacture of artificial eyes. (Five different coloured glasses have been produced and pronounced satisfactory, and the production of further colours is proceeding.)
7. An investigation on the durability of lead glasses and the possibility of effecting an improvement in them.

A great accession of work has also come to the Department through the request of the Refractories Research Committee of the Society of Glass Technology that systematic investigations on glass refractory materials should be set on foot. At the present time there is proceeding the systematic investigation of the composition, drying and firing, shrinkage, porosity, and density of nearly thirty British fireclays suitable for pots and other articles. Twenty of the clays have been analysed, and the other properties mentioned have for ten clays been ascertained over the range of temperature between 20° and 1400°.

III. Further problems suggested for research in due course are:—

1. An investigation on the production and properties of fused arsenic sulphide glasses.
2. The determination of the viscosity of different glasses in the fused state and its variation with temperature
3. The production of a protective coating on the inner surface of glasshouse pots.
4. An investigation into the heat losses in glass furnaces.
5. An investigation into the nature and cause of formation of a white crust which frequently appears on the surface of lead glasses during melting.

In connection with the problem of the production of a soft, workable glass, free from lead, suitable for lampworking, six of the best Continental types of glass tubing have been obtained and analysed, and a Bulletin has been issued stating their composition.

The Committee has considered the reports presented on the work done on the research programme drawn up in May, 1918, and expresses its satisfaction with the progress made. As so much work remains to be done on some of the incompleted investigations, and as further problems have been added to the list as they arise, the Committee does not consider it necessary at the present to draw up a new research programme.

The question of further furnace equipment, particularly for the attainment of very high temperatures, is now under consideration, and developments are hoped for in the near future.

REPORT OF THE COMMITTEE ON EDUCATION AND TECHNICAL TRAINING.

One meeting of the Committee has been held at which it was reported that the results of the Local Centre Examinations had been received, with results as follows:—

First year course, 14 candidates, 6 passed.

Intermediate course, 9 candidates, 8 passed, 3 with distinction.

Final year course, 9 candidates, 6 passed, 1 with distinction.

In the special Fourth Year Course, 7 candidates presented themselves for examination, and all were successful.

Copies of the draft ordinances for a Degree Course in Glass

Technology were presented and form an appendix to this report. The Committee desires to draw attention to the fact that an alternative four years' course is proposed in order to meet the requirements of students who, either from choice or from necessity, are called on to spend half of the year in the glass factory.

The Committee notes with satisfaction that the proposal of the Delegacy to exempt holders of the Technological Certificate in Glass from the first year of the Diploma Course has been approved by the University Senate.

The programme of educational work for the year 1919—1920 was considered. It was decided to recommend that the local centre courses be held at any of the following centres from which applications were presented:—Barnsley, Castleford, Derby, Knottingley, Mexborough, Sheffield, and York.

Proposals were made also that a similar set of courses should be made available in London, and that the governors of the Sir John Cass Technical Institute should be invited to co-operate in the undertaking.

It was further proposed, in order to stimulate general interest in technical education in glass, that special courses, each consisting of five or six lectures on

(*a*) Glass works accountancy,
(*b*) The design of glass furnaces,
(*c*) Engineering devices for the flint glass trade,

should be given in centres where adequate arrangements could be made. It is recommended that a course be delivered in the Stourbridge district, from which a promise of facilities had already been received.

W. Ripper (*Chairman*).
W. E. S. Turner (*Secretary*).

APPENDIX.

Draft Ordinances for the Degree of Bachelor of Science Technology.

The degrees to be awarded in the Department of Glass Technology are:—

Bachelor of Science Technology—B.Sc.Tech.
Master of Science Technology—M.Sc.Tech.
Doctor of Science Technology—D.Sc.Tech.

DEGREE COURSE IN GLASS TECHNOLOGY.

Ordinary Degree of Bachelor of Science Technology.

A student may select either the three or the four years' course. In the former he spends his time wholly at the University except for a period of his long vacation, which must be spent at a works; in the latter six months of each year the student attends lecture and laboratory courses and the remainder of his time at a works.

A. *Three Year Students.*

The Intermediate Examination.

Candidates for the Intermediate Examination must furnish certificates of having passed the Matriculation Examination of the Joint Board of the Universities of Manchester, Liverpool, Leeds, Sheffield, and Birmingham, or an examination accepted by the Board as equivalent to the Matriculation Examination, and of having attended for at least one University year subsequent to matriculation a course of study approved by the University in each of the subjects in which they present themselves for examination.

Candidates who present themselves for the Intermediate Examination shall be required to satisfy the examiners in the four following subjects:—

(i) Pure mathematics.
(ii) Physics.
(iii) Chemistry.
(iv) Glass technology.

They must also furnish evidence of satisfactory acquaintance with either French or German.

The Final Examination.

Candidates for the Final Examination must furnish certificates of having passed the Intermediate Examination, or of having received exemption, and of having attended for at least two university years a course of study, approved by the University, in all the subjects in which they present themselves for examination.

No candidate shall be permitted to enter upon the final year's course of study before he has passed the Intermediate Examination unless specially exempted.

Candidates who present themselves for the Final Examination shall be required to satisfy the examiners in the following subjects:—

(i) Glass technology.
(ii) The physical chemistry of glass.
(iii) Fuels, refractory materials, and pyrometry.
(iv) Geology and mineralogy of glass-making materials.
(v) Economics of the glass industry.

They must, in addition, furnish certificates showing that they have attended and made satisfactory progress in the following subjects of study:—

(*a*) Engineering principles, including applied mechanics, heat engines, and electro-technology.
(*b*) Mechanical drawing.

The candidates' knowledge of the foreign literature on glass shall be tested in the examination papers set.

B. *Four Year Students.*

The Intermediate Examination.

Candidates for the Intermediate Examination must furnish certificates of having passed the Matriculation Examination of the Joint Board of the Universities of Manchester, Liverpool, Leeds, Sheffield, and Birmingham, or an examination accepted by the Board as equivalent to the Matriculation Examination, and of having, subsequent to matriculation, attended courses in the above subjects.

Candidates who present themselves for the Intermediate Examination shall be required to satisfy the examiners in the following subjects:—

(i) Pure mathematics.
(ii) Physics.
(iii) Chemistry.
(iv) Glass technology.

They must also furnish certificates of having attended regularly and made satisfactory progress in:—

(*a*) Mechanical drawing.
(*b*) Heat engines.
(*c*) French or German.

The Final Examination.

Candidates for the Final Examination must furnish certifications of having passed the Intermediate Examination, and of having attended for at least two winter sessions a course of study, approved by the University, in all the subjects in which they present themselves for examination.

No candidate shall be permitted to enter upon the Final course of study before he has passed the Intermediate Examination.

Candidates who present themselves for the Final Examination shall be required to satisfy the examiners in the following subjects:—

- (i) Glass technology.
- (ii) Physical chemistry of glass.
- (iii) Fuel, refractory materials, and pyrometry.
- (iv) Geology and mineralogy of glass-making materials.
- (v) Economics of the glass industry.

They must, in addition, furnish certificates showing that they have attended and made satisfactory progress in the following subjects:—

- (*a*) Theory of machines.
- (*b*) Electro-technology.

The candidate's knowledge of the foreign literature on glass shall be tested in the examination papers set.

Department of Glass Technology,
The University, Sheffield.

XV.—*Some German Glassworks in March and April*, 1919.

By S. N. Jenkinson.

The glass industry is larger and more important than either the British public or the average manufacturer realises.

To Germany, however, it actually was an important industry giving employment to a large number of her population and bringing wealth into the country, since 75 per cent. of her glass products were exported. As evidence of its importance, there can be quoted the fact that in 1913 the German export of glass was valued at 123 million marks, the export of toys was 103 million marks, and of pottery 94 million marks. Consider these figures, and remembering, too, the large exports of Austria and Belgium, one can at once realise the magnitude of the glass trade and how neglected it has been in our own country.

In regard to the number of persons employed, returns are available of such persons as are members of trade unions in the glass industry, but the figure is small compared with the actual number employed. I myself estimate the number employed at well above three millions. Let us remember that, whilst this huge army of workers was busy in Germany, men in Great Britain were unemployed because Germans were making the glass that could have been made in this country. Certainly the glass was cheap, but that is of little use to a Britisher out of a job, with no money to buy the cheap glass. How I wish that this elementary fact could be brought home to some of those men of wisdom who at certain seasons of the year congregate in London.

The War gave a knock-out blow to the German glass industry; exports ceased, and men were called up either for military service or for munition work—in fact, the trade closed down. Towards the end of 1915, however, it was realised that certain glass articles were essential for the well-being of the nation, and fuel was accordingly supplied to a number of works to permit of operation. If a firm had several furnaces only one was run, and preference was given to works in small country towns where munition work was not available. Those firms able to operate charged exorbitant prices for goods, for a combine of manufacturers was formed, and a proportion of the profits handed over to those firms whose furnaces were not permitted to run. This policy was adopted with success by several industries in Germany, and in particular by the boot and shoe trade. By such means all the works were kept in good repair and their financial resources conserved with the view to a speedy return to pre-war production when the opportunity offered.

This was approximately the position until the Armistice. But at the time of my visit I found that the position had changed greatly. Orders were plentiful at remunerative prices, skilled labour was available, and there were no stocks either in the hands of manufacturers or dealers or retailers. Many British manufacturers would do better if they attended to their works instead of worrying about stocks of glass in Germany which do not exist.

In Germany as a whole, practically no one is at work, although eager to do so. The glass trade is to all intents and purposes at a standstill. In Saxony, for example, out of thirty-two glass firms with 117 furnaces, only eight furnaces were found at work. There is no coal to be had. Large parts of Germany depended upon

Bohemia for coal, but the Czecho-Slovaks will not export it now except in exchange for food, which the Germans do not possess.

Other districts depend upon the railways to bring them their coal; but at present the German railways cannot cope with even the small volume of traffic offered to them. The same applies to raw materials, and the position is aggravated by the absence of food and clothes; in fact, everything is wanting. The shortage is more serious than it appears; only a small percentage of the German factories are at work, and if more were in operation the railways could neither transport the necessary raw material nor remove the finished product.

It is difficult to convey an impression of the German people themselves. They are without employment, without food, without clothes, month after month; they are without food and clothes, not because they have no money (money has no value in Germany), but because there is neither food nor clothes in Germany. They want to work but cannot. To me they seemed a people entirely without hope. Whatever the future may bring forth, they feel that it cannot be worse than the present.

I found that rates of wages varied greatly, but in no case do they approach the standard of Great Britain. In one district one mark an hour was paid, and this was looked upon as a high rate which would be reduced when normal times came nearer. It is obvious that the British manufacturer cannot compete with goods produced at such rates.

Although fuel is lacking and transport extremely inadequate, I must warn you that the furnaces, plant, and machinery have all been maintained in first-class condition; the works are ready to produce on a scale equal to, if not greater than, their pre-war scale. The owners are determined to capture their lost trade. They have money with which to develop their businesses, although personally I believe that this will all be used up long before normal conditions return. Their labour is really skilled, their blowers work on better and quicker methods than ours, their furnaces and plant are better, and their organisation is superior. The firms employ engineers, chemists, and highly trained technologists, who study their jobs and analyse their problems. In a word, their management is technical and better than ours. If a manager or working director is asked a question, he can answer it and does not have to go to his glasshouse manager for the information, as is so often the case in Great Britain.

It may be of interest to note, however, that apparently there have been no developments in feeding devices or blowing machines in Germany during the War.

Now as to the general conclusions from my visit, I am convinced that there is nothing to fear from Germany. No glass will come out of Germany for a long, long time to come; it is not a question o months, but probably of years. British manufacturers, therefore, have their chance if they will only take it. Let them instal modern plant and furnaces and let them employ trained technical men. If glass manufacturers could realise how useless a non-technical man is in a works, they would make quicker progress.

If we do as I suggest, we should be able to compete on more level terms, although as long as the standard of living on the Continent remains lower than in this country, our industry must continue at the mercy of those who believe in employing Germans while our own working men are idle and, maybe, their families in want.

Edinburgh and Leith Flint Glass Co.
Norton Park, Edinburgh.

XVI.—*Note on the Preliminary Firing of Tank Furnaces.*

By Elbert E. Fisher.

In September last I had the pleasure of a visit from Mr. J. Connolly and Dr. W. E. S. Turner. Amongst the many subjects which were discussed was that of the preliminary firing of tank furnaces prior to charging them with batch. Both Mr. Connolly and Dr. Turner were strong advocates of heating up the furnace to as high a temperature as possible prior to charging in any cullet at all, in order that the tank blocks may become previously vitrified, and therefore more resistant to the action of glass. Mr. Connolly, indeed, said that he himself at his works had tried this practice and believed strongly in it.

These views were of the greatest possible interest to me, since my own practice has been similar. In my view, it is advisable to maintain the tank empty at the highest possible temperature prior to charging, in order that the production of *sillimanite* may take place to the greatest extent possible and produce resistant tank blocks.

It may be of interest to other workers to have a note of the schedule to which I have worked. The schedule states the dates of one such operation carried out during the summer with the successive temperatures attained on the different dates. The schedule is as follows:—

“Aug. 12	Light fire in checkers
13	,, ,, ,, side burners.
15—6 a.m.	200° F.
16	350
17	500
18	700
19	900
20	1125
Aug. 21	1350° F.
22	1550
23	1775
24	2000
25	2200
25—6 p.m.	2650
26	2700

Fill in cullet and proceed to fill tank with suitable batch and cullet, and start work when filled.”

The tank in question had a melting end the internal dimensions of which were 20½ by 14 feet, and its output in twenty-four hours amounted to 40—45 tons.

In my view, a tank furnace in which the above method is operated will outlast by months one in which the old method is adopted of adding cullet prior to heating.

The Modern Glass Co.
Toledo, Ohio.

XVII.—*Some Recent Improvements in the Designs of Glassworks Furnaces and Gas Producers.*

By J. S. Atkinson.

(*Read at the Leeds Meeting, October* 15*th*, 1919.)

The author must commence this paper with an apology. By his having accepted the invitation of the Council to read a paper on the design of glass furnaces, it might be expected that he was held to have some special knowledge of glass-making. He particularly wishes to emphasise the fact that he lays no claims to any such knowledge. The design of the pot furnace, which will be described later, is the product of many years' experience in steelworks practice. This experience was applied some three years ago to the glass industry with most satisfactory results; results which the author believes have not been equalled by any other type of pot furnace at present being constructed.

The Design of Gas Producers.

Before proceeding with the question of furnace design, it is necessary to deal with the design of gas producers, because, no matter how perfect a furnace is, satisfactory results cannot be obtained if the supply of gas is faulty, by reason perhaps of its irregular quality or quantity.

The importance of the gas supply being both regular in quality as well as in quantity will be fully appreciated by all who have had practical experience in gas-fired furnaces. The author believes that this matter is of more vital importance in many glass processes than even in steel works practice, where it certainly has a very great bearing on the quality of the finished product.

The old coal-fired furnace is being rapidly replaced by the gas-fired furnace. More particularly is this true, perhaps, in steelworks than in glassworks. It must, however, be admitted that many practical men are prejudiced against gas firing because of their experiences with faultily designed producers and furnaces, which are in many cases the conception of individuals who have had no real practical or scientific training, and have no actual ability other than perhaps that of being good salesmen.

In the choice of the type of producer, local conditions must be taken into consideration. The fuels available in this country for use in a producer are coke and coal. In small installations there is much to be said in favour of coke, providing it can be obtained at anything like a reasonable price. In a properly designed coke gas producer a uniform supply of gas, both as regards quantity and quality, can be obtained, and the outstanding feature of this type of producer is that it can be run with unskilled labour, a very important advantage in these times.

Fig. 1 (p. 150) shows the design of such a coke gas producer.

The grade of coke used is ordinary unselected gasworks coke. The latter is charged into the producer through the hoppers fitted into the producer arch. Either one or two hoppers are provided, according to the size of the producer. Fire bars are provided, on which the fuel bed rests. No forced draught or steam pressure is required in this type, natural draught causing the inflow of air through the adjustable air inlet slide, which is fitted to the ash-pit door. Induced with the air is a certain amount of vapour, provided by a water supply to a channel section fitted close to the fire bars. In this channel are a series of slots which allow of a curtain of water-drops to fall in front of the fire bars. Due to the heat of the incandescent zone of the producer, these drops are vaporised, and the steam is drawn through the fuel bed. The reason for introducing the steam with the air is twofold: first, the presence of steam reduces the working temperature of the producer and prevents the formation of clinker, which would occur if air only was used and the producer worked up to anything like its full capacity; secondly, the steam splits up into its elements as it passes through the incandescent zone, and the gas produced is enriched through the presence of hydrogen and an additional percentage of carbon monoxide, the percentage of nitrogen in the gas being reduced.

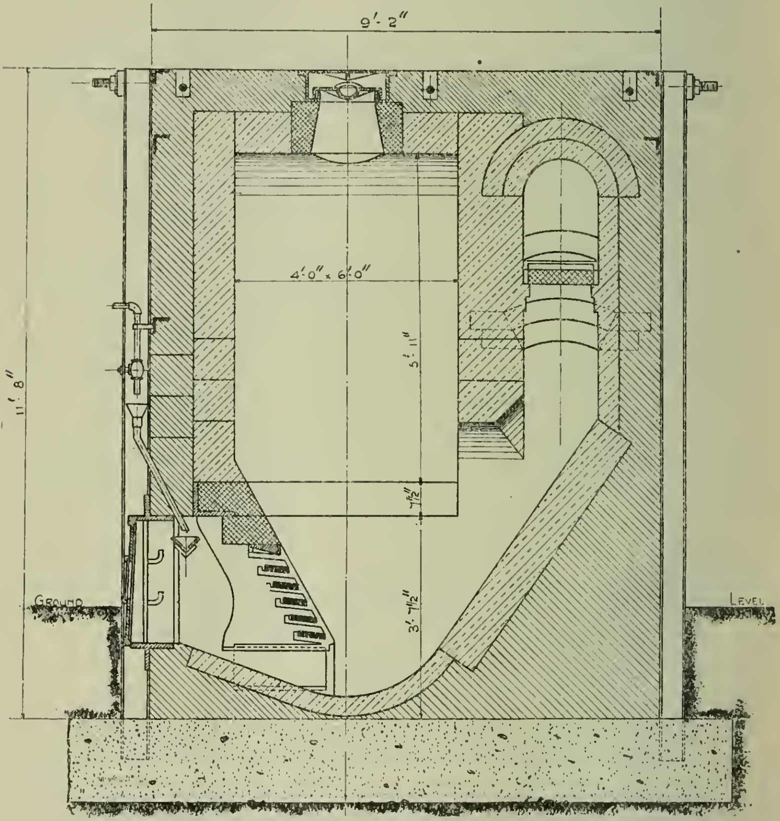


FIG. 1.

An important feature in this design of producer is that the gas outlet is not placed over the fuel bed, but is situated some distance down the side of the producer. When working the producer, the fuel level should never be allowed to fall below the top of the gas outlet. There are two very pronounced advantages arising from this arrangement:—

(1) As the path of the air and steam passing through the incandescent zone always remains at a constant length, a gas of absolute uniform composition is produced. In the ordinary arrangement of producer, where the gas outlet is situated over the fuel bed, the thickness of the fuel bed will often govern the quality of the gas produced.

(2) The space above the gas outlet and below the charging hoppers is utilised for a reserve supply of coke, and about twelve to twenty-four hours' supply can be stored here, thus avoiding the necessity of charging the producer more than once or twice in the twenty-four hours. The coke falls, due to its own weight, into the incandescent zone as required, no poking being necessary.

In this type of producer, the only attention that is required is the charging once or twice in the twenty-four hours, the removal of the ashes, and the clearing of the fire bars. This work can be done by unskilled labour, and occupies in practice a total of about one and a-half hours per producer each twenty-four hours, six operations in all being required, that is to say, four cleaning operations of about a quarter of an hour each, and two charging operations of the same duration.

Comparing this with the ordinary producer using coal, a great saving in labour is shown. In the latter, frequent stirring of the fuel bed is essential if good results are required. Moreover, such work has to be carried out by experienced gasmen, whose wages are greatly in excess of the unskilled labour required in the producer using coke.

The rate of gasification in the coke producer is under complete control, the only adjustment which is required being to the air inlet slide previously referred to. The producer can be placed either close up to the furnace it feeds or at any convenient distance away from it. The former arrangement is the one most general, although the importance of keeping the producer close up to the furnace is often, in the author's opinion, overestimated; in fact, this question should be decided more from the point of view of convenience of arrangement of the plant and the supply of fuel to the producers.

Fig. 2 shows a battery of coke gas producers of the design described. These producers are placed at some distance from the furnaces they are serving.

If it is a question of supplying gas to a small furnace installation, and coke is not available, then a Siemens' dry bottom producer, using coal as fuel, can sometimes be employed with advantage, although, in the author's opinion, this type of producer should only be used under exceptional conditions.

As in the case of the coke producer, no forced draught or steam pressure is necessary, and this fact is the only one which should govern users in favour of its selection in cases where the provision of forced draught or steam pressure would be difficult. A very great objection to the producer is that an irregular supply of gas, both as regards quality and quantity, is produced. This is due to the fact that at each fresh charge the volatile matter from the new coal dropped on to the fuel bed is rapidly driven off, and for a brief period an increased volume of gas much richer than the normal is produced. These fluctuations prevent proper furnace temperature control and also cause a wastage of gas. Moreover, it is essential in certain classes of glassware produced from tank furnaces to maintain uniform conditions as regards furnace atmosphere; therefore a sudden rush of gas, causing a smoky flame, would prevent these conditions being fulfilled, and the finished product would suffer.

To overcome the difficulty of the irregular rate of gasification from such types of producers, a number may be arranged to feed into a common gas flue.

Types of producers which have been and are still in very general use in this country are the Dowson, Duff, and Wilson. All these producers have a feature in common, namely, a water seal at the bottom which allows of constant gas-making during the clearing out of ashes, a great advantage over the Siemens' dry bottom producer.

The Dowson, Duff, and Wilson producers all have the disadvantage referred to in the Siemens' type, that is, the fluctuation in the quantity and quality of gas produced, due to intermittent charging.

Revolving grate producers have during recent years come very much to the front, and with certain grades of fuel and where a number of producers are required in batteries they possess great advantages. Their selection, however, should not be made too hastily. Makers of such types of producers will sometimes claim that they will deal with practically any kind of fuel, highly caking coals included. This often leads to great disappointment to those who instal them, and in the author's opinion the revolving grate producer is mainly useful for dealing with fuels containing a very high percentage of ash, where in fixed grate producers the clearing out of the ashes by hand entails very arduous work. Revolving grate producers cost from twice to three times as much as fixed

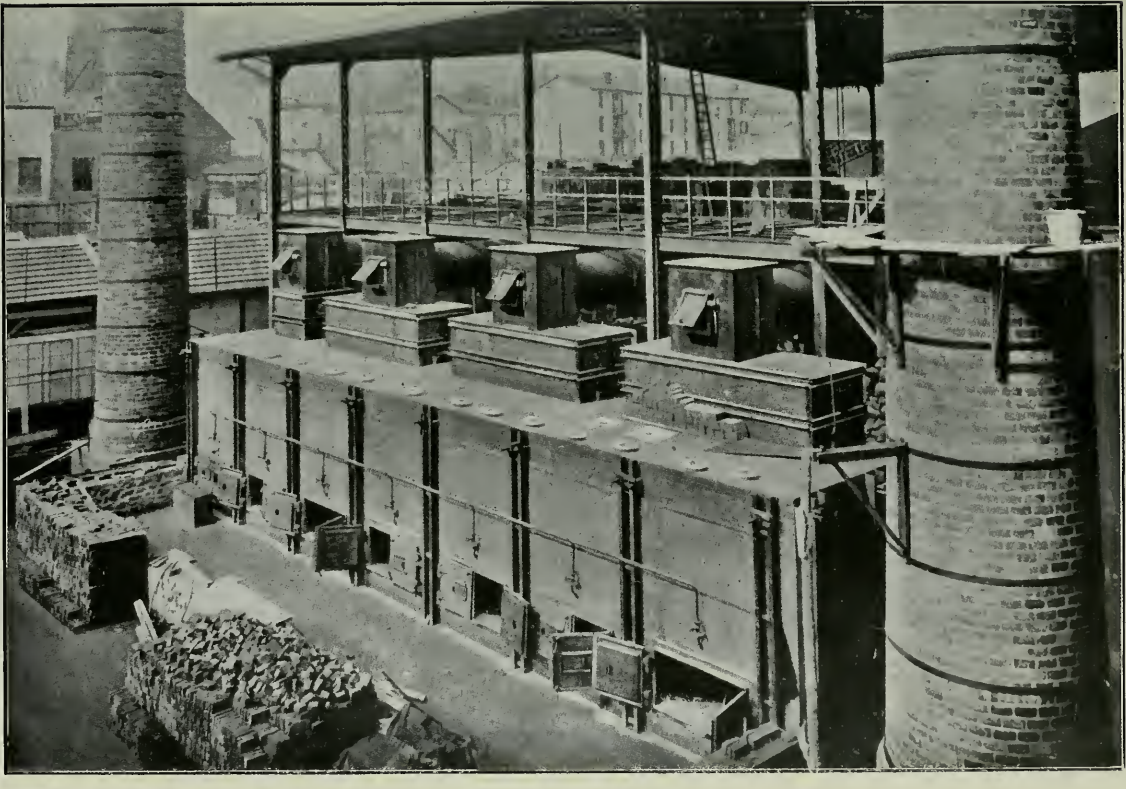


FIG. 2.

[*To face p* 152

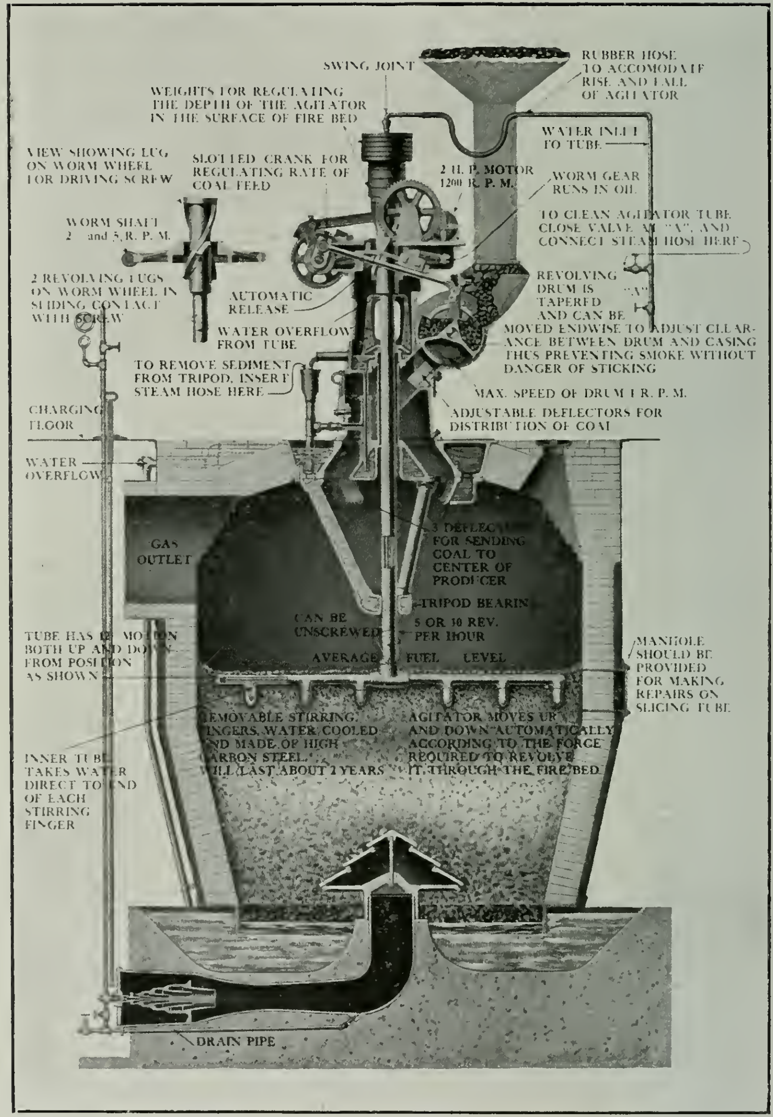

SWING JOINT
RUBBER HOSE TO ACCOMODATE RISE AND FALL OF AGITATOR
WEIGHTS FOR REGULATING THE DEPTH OF THE AGITATOR IN THE SURFACE OF FIRE BED
WATER INLET TO TUBE
VIEW SHOWING LUG ON WORM WHEEL FOR DRIVING SCREW
SLOTTED CRANK FOR REGULATING RATE OF COAL FEED
2 H. P. MOTOR 1200 R. P. M.
WORM GEAR RUNS IN OIL
WORM SHAFT 2 and 5 R. P. M.
TO CLEAN AGITATOR TUBE CLOSE VALVE AT "A", AND CONNECT STEAM HOSE HERE
2 REVOLVING LUGS ON WORM WHEEL IN SLIDING CONTACT WITH SCREW
AUTOMATIC RELEASE
REVOLVING DRUM IS TAPERED AND CAN BE MOVED ENDWISE TO ADJUST CLEARANCE BETWEEN DRUM AND CASING THUS PREVENTING SMOKE WITHOUT DANGER OF STICKING
"A"
WATER OVERFLOW FROM TUBE
TO REMOVE SEDIMENT FROM TRIPOD, INSERT STEAM HOSE HERE
MAX. SPEED OF DRUM 1 R. P. M.
CHARGING FLOOR
ADJUSTABLE DEFLECTORS FOR DISTRIBUTION OF COAL
WATER OVERFLOW
GAS OUTLET
3 DEFLECTORS FOR SENDING COAL TO CENTER OF PRODUCER
TRIPOD BEARING
CAN BE UNSCREWED
5 OR 10 REV. PER HOUR
TUBE HAS [illegible] MOTION BOTH UP AND DOWN FROM POSITION AS SHOWN
AVERAGE FUEL LEVEL
MANHOLE SHOULD BE PROVIDED FOR MAKING REPAIRS ON SLICING TUBE
REMOVABLE STIRRING FINGERS, WATER COOLED AND MADE OF HIGH CARBON STEEL. WILL LAST ABOUT 2 YEARS
AGITATOR MOVES UP AND DOWN AUTOMATICALLY ACCORDING TO THE FORCE REQUIRED TO REVOLVE IT THROUGH THE FIRE BED
INNER TUBE TAKES WATER DIRECT TO END OF EACH STIRRING FINGER
DRAIN PIPE

Fig. 3.

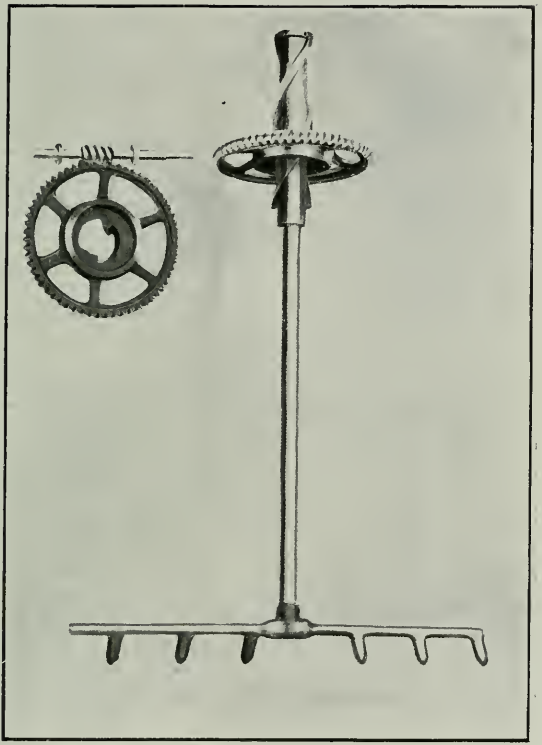


Fig. 4.

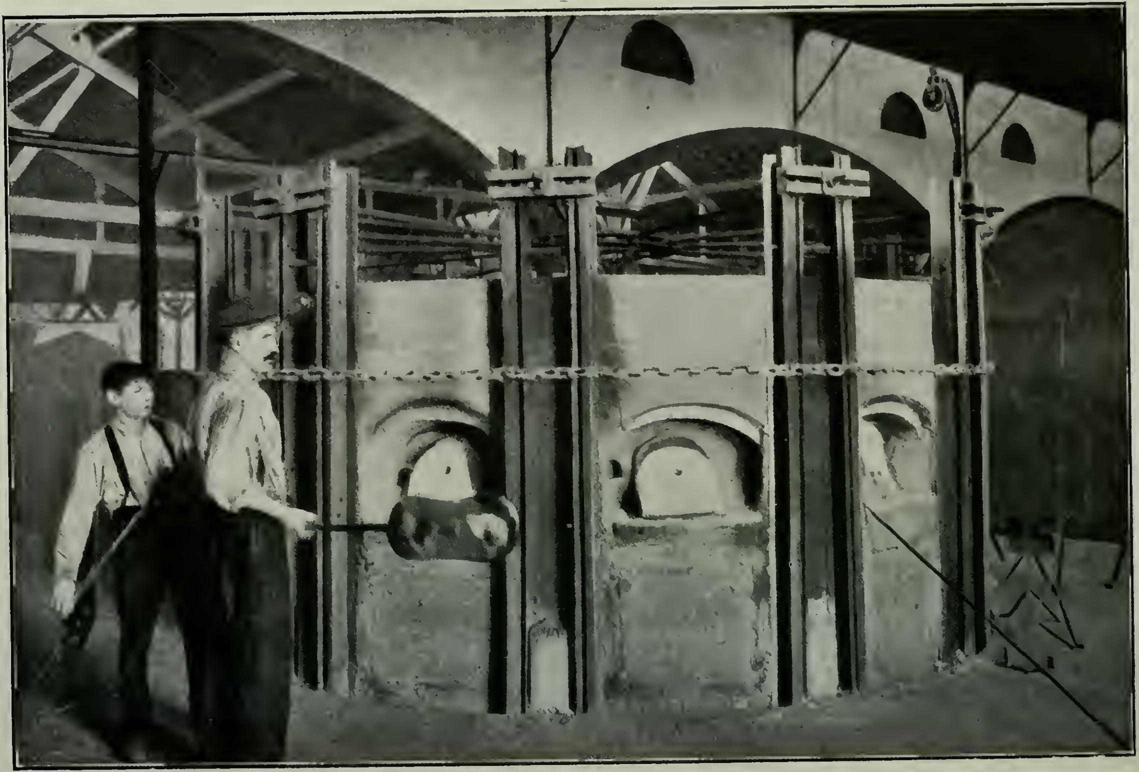


FIG 5.

grate producers, and the expenditure on upkeep is high. For this reason many users have returned to the more simple non-mechanical types.

In order to approach as nearly as possible to the theoretically perfect producer, three primary conditions are essential:—

(1) Constant and controllable feed of the fuel to the producer.

(2) The even distribution of the fuel over the whole of the producer bed.

(3) The constant agitation of the upper portion of the fuel bed.

These conditions are met, to a more or less satisfactory degree, in the Talbot, Wood, Hughes, and Morgan producers. The Chapman agitator, with automatic feed, fulfils all these conditions, and has the additional advantage that it can be fitted to nearly all types of existing producers.

Fig. 3 shows a producer fitted with the Chapman agitator and automatic feed. As far as the automatic feed is concerned, there is nothing very novel in its design, excepting perhaps that there is a small but heavy toothed roller placed immediately above the feed drum, which prevents the coal from forming a bridge and also acts as a crusher, breaking down any large lumps before they enter the feed drum. The feed drum is divided into three chambers, which allows of three small charges of fuel being fed to the producer at each revolution of the drum, and as the drum revolves at a speed of about one revolution per minute, it will be seen that there is practically a constant supply of coal delivered to the producer. Adjustable deflectors are provided for the distribution of the coal over the fuel bed. The even distribution, however, is completed by the agitator.

The agitator itself, which is the essence of this invention, consists of a water-cooled, horizontal floating stirrer fitted with dependent projections or stirring fingers. The stirring arm is fitted on to a vertical shaft driven through a worm reduction by an electric motor. The worm wheel is not fixed rigidly to the vertical driving shaft, but is attached by means of a special driving head, which constitutes the principal feature in this drive.

Fig. 4 shows this driving head more clearly. The worm wheel has two inner projecting surfaces which are in sliding contact with inclined screw-threads formed on the driving shaft. The vertical driving shaft carrying the agitator arm will by this arrangement rise and fall according to the power required to rotate it. This means that the agitator rises and falls with the level of the fuel bed, the agitator arm remaining normally a few inches below the level of the fuel.

The cycle of operation in a gas producer is from one ash removal to the next, usually a period of from twelve to twenty-four hours. When the required amount of ashes has been shovelled out and the remaining ashes have settled, the fuel bed drops abruptly from one to two feet, dependent upon the amount of ash removed. Then for the ensuing period of the cycle the fuel bed gradually rises until the ashes are removed again. It is therefore evident that any mechanical agitator, in order to do its work properly, should "float," that is, should rise and fall with the fuel bed. This is the chief feature of the Chapman agitator.

Should the stirring arm or fingers come into contact with large lumps of clinker, they rise automatically over them, and there is no risk of the arm or fingers being broken, as is the case in rigid agitators, which are employed in most of the types of mechanical producers previously referred to.

The agitator revolves at a much higher speed than is usually the case with other types, the speed of the Chapman agitator being from five to ten revolutions per hour. This, of course, tends to give better conditions in the producer, as each section of the fuel bed is stirred very frequently. In spite of this fact, only a two h.p. motor is required to drive both the agitator and the feeder. The reason for this small amount of power being required is that only light portions are moved, namely, those which actually do the work, and not heavy portions of the producer, such as the top or side walls, which is the practice in certain other designs. Moreover, another reason for the low power is the floating device, which automatically confines the power requirement to the normal.

Balance weights are provided, and upon the weight of these depends the distance below the level of the fuel bed that the agitator will operate at.

Chapman agitators are now installed in fifty-one different glassworks in America, and a number also in Canadian and Japanese works. In all, 175 agitators are in service in glassworks.

As compared with producers without mechanical agitation, the author has received data from users which show the following advantages of the agitator:—

(1) From 50 per cent. to 100 per cent. increased producer capacity is obtained. For example, in an ordinary producer without mechanical agitation, if the rate of gasification was 10 cwt. per hour, with the addition of the agitator the rate of gasification would be increased to 15 cwt. to 20 cwt. per hour.

(2) Gas of more constant B.T.U. value is produced.

(3) The calorific power of the gas is improved by at least 10 per cent.

(4) With the exception of the period immediately after ash removal, hand poking is eliminated.

(5) It is often possible to reduce by one-half the number of producers serving any given furnace installation by the addition of the agitators, and as the labour on each individual producer fitted with the agitator is considerably lessened, the total labour requirements on an installation of several producers is greatly reduced.

(6) As the gas produced has a uniform calorific power, and the amount produced is constant, it is possible to regulate the air inlet valves on the furnaces in such a manner as to obtain complete combustion with a minimum of excess air. This often leads in practice to very important savings in the amount of gas used in the furnaces, up to 10 or 15 per cent.

The Stein Recuperative Furnace.

Turning to the question of furnace design, Fig. 6 shows the Stein type recuperative pot furnace, installed at the works of Messrs. Houdaille and Triquet, Choisy-le-Roi, near Paris, by the author's firm. At first glance this furnace appears to be somewhat similar to the Hermansen furnace; in reality, however, the construction is very different. In the Hermansen furnace the recuperative chambers are situated immediately under the furnace, whereas in the Stein furnace the recuperative chambers are placed on each side. This arrangement allows of the recuperators being completely isolated from the flow of glass occurring in the event of one of the pots becoming cracked or broken, and for this purpose glass pits are arranged, one at the bottom and one on each side of the central burner. The two latter pits are in connection with the flame outlet passages. In the event of a broken pot and the glass finding its way into the flame outlet passages and into the two outer pits, the glass is kept in a state of fusion right up to the stopper openings in the pits, as the flame follows the path of the glass.

Again, the system of recuperation is completely different from that used in the Hermansen furnace or any other type of glass furnace installed in this country. In the Hermansen furnace, the air for combustion passes through horizontal passages, and the outgoing products of combustion, which heat the air, pass through adjoining passages, which are also horizontal and run at right angles to the air passages. The circulation of the air through the horizontal passages is brought about by the chimney-pull, and therefore the flame pressure around the pots and in the upper part of the furnace must necessarily be slightly below the atmospheric. If, then, there is a leakage of the outer cold air through crevices in the brickwork of the side walls or roof, such a leakage may locally affect the temperature surrounding a pot and cause a cool spot, which often results in a cracked pot. In the Stein

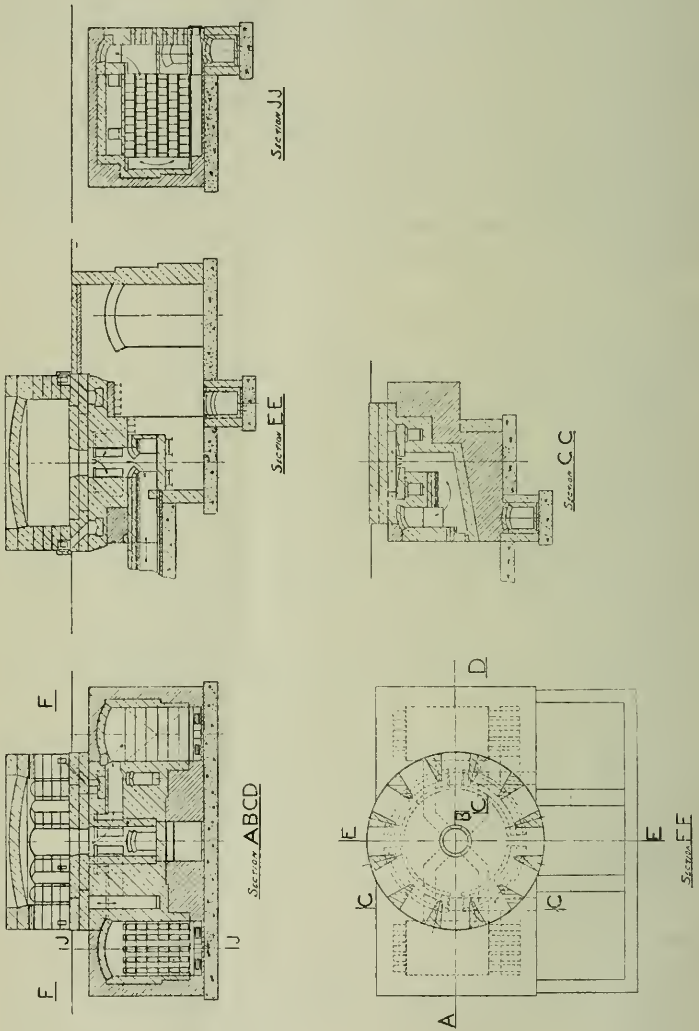


Fig. 6.

furnace the air passages in the recuperators are vertical, and there is a constant rise from the point where the air enters the recuperators to the point where it leaves them. As the air is heated as it passes up through the recuperators it becomes, of course, lighter than the atmospheric cold air. This, in conjunction with the regulation of the chimney damper, will allow of a positive flame pressure above the atmospheric pressure being maintained in the furnace around the pots; in fact, the whole of the space around the pots is fully filled with flame. This insures a very uniform temperature.

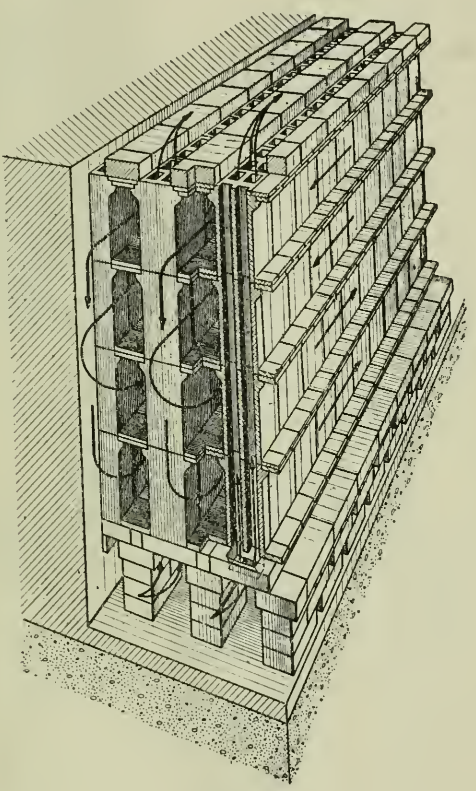


FIG. 7.

Fig. 7 shows a view in perspective of the special recuperator bricks.

In the Stein furnace the gas can be supplied by independent producers, or the producers can be built attached to the furnaces.

In a 12 covered-pot furnace with pots of 450 kilos capacity, installed in a French works, and producing glass for lamp chimneys and the like, the fuel consumption ranges from 2000 to 2500 kilos per twenty-four hours, the charge being melted and worked within this period. This fuel consumption is equal to from 37 to 46 per cent. of the weight of glass produced, and it must be pointed out that the amount of fuel used does not increase according to the length of time the furnace is in operation, but remains, as far as can be ascertained, constant.

Comparing results obtained by the best other types of pot furnaces, taking, for example, the Hermansen furnace, where the consumption is from 65 per cent. to 110 per cent. of coal of the weight of glass produced, it will be seen that the consumption of the Stein furnace is exceedingly low.

The Stein furnace referred to above was run for twenty-two consecutive months. It was then stopped so that an examination might be carried out in order to ascertain if the refractory lining required repair. It was found that only very minor repairs were necessary, and the furnace was again put to work, and has now been running for a total time of more than thirty-four months. There are at present no indications that it will have to be put out in the near future. The fuel consumption given above was taken after the furnace had been working for some considerable time.

Fig. 5 shows examples of Stein type pot furnaces.

As regards designs of tank furnaces, the author is afraid he cannot describe any very novel features. Fig. 8 shows the standard type of tank furnace his firm is at present constructing. Modifications from this design are made according to the local conditions. Possibly one feature may be new to some manufacturers, this being the arrangement of dampers, which allows of the individual control of the burners. When a furnace is first put to work, a high temperature is required throughout the length of the tank in order to melt down the batch, but once the batch is melted, the burners at the end of the tank remote from the charging end may be partially or completely closed down, leaving the burners at the charging end fully open in order to deal with the cold incoming charge. This arrangement tends to fuel economy.

In conclusion, it may be added that the special system of recuperators described in connection with the Stein pot furnace is now being applied to revolving pot furnaces used in conjunction with tank furnaces and Owens' glass bottle machines, and there are a number of these furnaces at present being erected in this country.

DISCUSSION.

Mr. J. H. Davidson asked what was the cost of the Stein furnaces with 8 or 12 pots, and their probable lifetime.

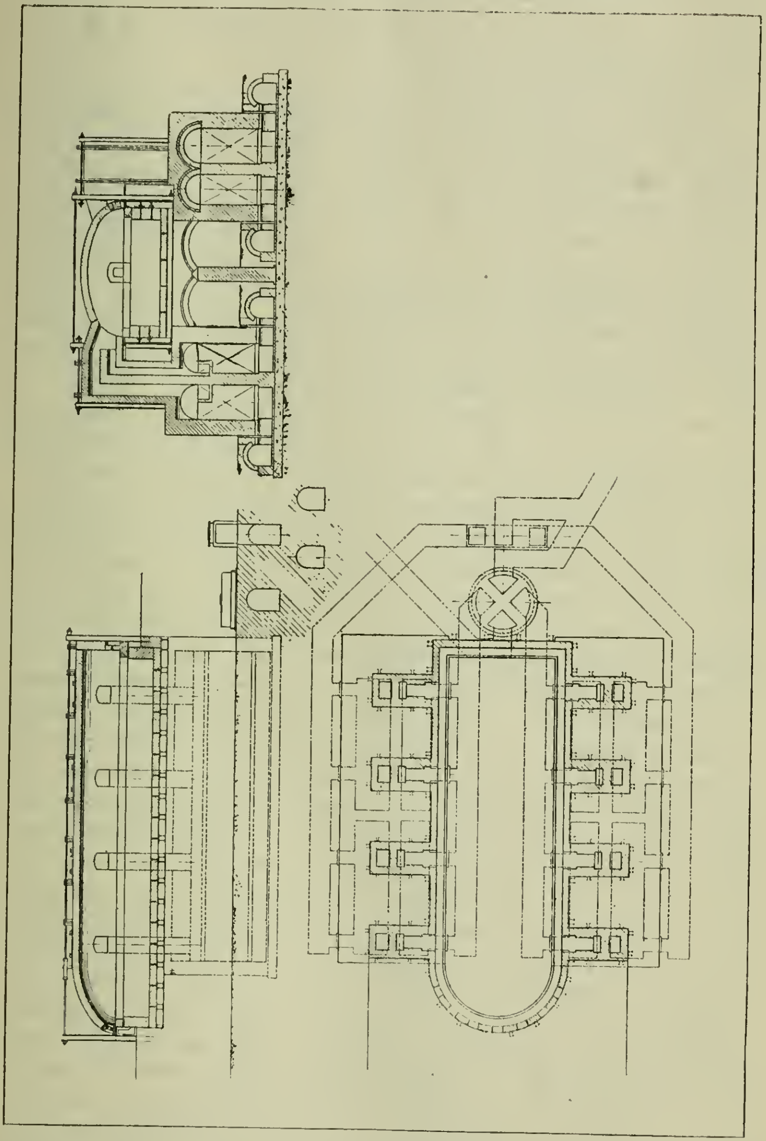


Fig. 8.

Mr. Atkinson stated that in metallurgical furnaces using the same system, the recuperators had stood for ten to twelve years in practice. There were more than 1000 Stein furnaces in existence, mostly in steel works, with the same recuperators. In no case, to his knowledge, had any of these recuperators been taken out.

The cost of an 8-pot furnace was approximately from £1400 to £1600, excluding the gas producer.

PROF. J. W. COBB wished to know whether Mr. Atkinson could give any figures supporting the view which he had expressed (and was often expressed by others) that water supplied to the grate bars of a producer cooled the fire materially and altered the composition of the gas. So far as his own observations went, the amount of water decomposed in such circumstances was not such as to make any appreciable alteration in the composition of the gas or to alter appreciably the temperature of the fuel bed as a whole, although it did undoubtedly loosen the structure of the clinkers just above the grate bars, and to that extent served a useful purpose. A steam-blown producer was on a different footing. In that case the quantity of steam passing through the fire was under control and more considerable in amount, and it did alter both the temperature of the fuel bed and the composition of the gas.

It was an interesting question as to how far the use of a water-cooled agitator in the producer had justified itself. Probably the best known of such devices was the Talbot stirrer. In an early form this was a shaft running down the centre line of the producer with two arms, a lower one working near the grate and designed to prevent the accumulation of clinker, and an upper one revolving near the surface of the fuel, spreading it and breaking up any caking lumps. This appliance was very difficult to keep in working order, and in a later form, which he had seen at work, the long shaft and lower arm had been discarded, apparently with good results. It was quite true that an effective agitator would increase the output of the producer, but it must not be forgotten that, as a necessary consequence, the liability to carry over fine dust in the stream of gas would be increased, and that this was a matter for serious consideration when the application of the device to a glass furnace was in question. There was a great deal to be said for the construction of the furnace which had been described. in which, in the first place, the furnace itself was treated as a separate unit, the producer being built outside, and in the second place the recuperators were made largely independent of the bed of the furnace and did not carry its weight. There would be some loss of sensible heat between the producer and the point at which the gas was burned, the floor space necessary would be greater than in a furnace with a built-in producer, and the cost of construction presumably higher, but compensating advantages would be secured. It was very difficult to make a useful comparison of the fuel consumption of furnaces as given by the makers in the form of so much fuel per ton of glass, on account of its ambiguity, and because so much depended on the kind of glass melted, the degree of planing required, and other circumstances. Although it did not seem so directly practical, he would very much like to see in addition a figure stated for the fuel required in relation to the volume of the furnace and the area of its working bed. Actually, working figures of fuel per ton of glass could be made useful if they were given in a very specific form and made representative of actual working over some considerable period, but the conditions were seldom satisfied.

Mr. Atkinson, replying to Prof. Cobb's first remarks, said that, as regards the coke producers described, the explanation was that water was not dropped on to the fire bars, but in front of them in a curtain of drops, which were vaporised and drawn into the producer with the air. Experience had shown that there was a marked effect on the gas.

Some differences were then noted between the Talbot stirrer and the Chapman agitator. The former was rigid, while the latter was a "floating" agitator which rose automatically over any large obstacles, such as large pieces of clinker, which it encountered, preventing any undue strains in the agitator arm, and also admitting of the agitator rising and falling to the level of the fuel bed. Again, with the Chapman agitator the speed of agitation was much greater than in the Talbot. With regard to dust, he agreed with Prof. Cobb, but the trouble could be remedied by installing suitable dust catchers.

As for loss of heat between the producer and the point at which the gas was burnt, this was insignificant in practice, and not important if there was ample recuperative power. In the case of a 12-pot furnace, each pot having a capacity of 450 kg., making glass for lamp chimneys, the consumption of fuel was from 200 to 250 kg. of coal per twenty-four hours, the charge being melted and worked within the twenty-four hours.

Answering another question, Mr. Atkinson said that the temperature attained was less with coke than with coal, but, if necessary, a temperature of 1500° could be attained with coke.

Mr. F. Wood remarked that in some cases it was found that the labour bill was stationary even after putting down automatic producers. There were, he said, two schools of thought: the first said you must roll but not agitate; the second said you must agitate. In the case of the Talbot stirrer, the arm was only

5 inches below the surface of the fuel, and it was a question whether a single heavy arm was better than more delicate ones.

Mr. W. J. Rees said that the figures given by Mr. Atkinson as to fuel consumption in relation to glass produced represented such a great advance in efficiency over any other type of furnace, either recuperative or regenerative, with which he was acquainted that he would be glad to know if the fuel consumption given related to

(*a*) the weight of finished glass produced;

(*b*) the approximate weight of glass produced, deduced from the capacity of the pots; or

(*c*) the weight of glass batch (or glass batch plus cullet) melted.

In either case, in order to understand the value of the ratios given, he considered it desirable for the approximate composition of the batch to be stated and the proportion of batch to cullet used. He would also ask if the figures given represented a particular week's run of the furnace or a general average over a period of months; this was important, as furnaces, particularly tanks and open-pot furnaces, frequently fell off in efficiency after a few months' life from easily understandable causes.

In recuperative furnaces a great deal depended on the proper choice of refractory materials and upon efficient bricklaying in order to avoid leaks. In this Stein furnace, which had been so lucidly described by Mr. Atkinson, the design and construction of the recuperators was such that a considerable efficiency would be expected. The design of the recuperator bricks was excellent, and he would like to ask if Mr. Atkinson could say if it had been found necessary to use specially selected clays in their manufacture, and if any difficulties had been experienced either in the recuperators or other parts of the furnace through the failure of the refractory materials. Sufficient consideration was not always given to this question, namely, of a proper choice of refractory materials, although it was of vital importance in regard to the life of the furnace, especially so in recuperative furnaces; and it appeared evident from the figures given by Mr. Atkinson as to the life of the recuperators that very great care had been used in the selection of refractory materials, which well fulfilled the duty imposed on them.

Mr. Atkinson replied that the figures given were the average of several tests, not of a special one. The fuel consumption was from 37 per cent. to 46 per cent. of the weight of glass melted.

Prof. Fearnsides commented on the thinness of the walls of recuperators. There was no doubt that the heat treatment was different from what usually occurred. He would like to know if there were any figures comparing the consumption of fuel in the case of furnaces erected in England and in France, as much of the success of furnaces in the latter country was due to the careful work of the bricklayers. Absence of leaks undoubtedly increased efficiency. With regard to dust, he inquired whether any account had been taken of different kinds of coal. In the United States a partially coking coal was sometimes used. Agitators might be good with coking coal and bad with non-coking coal, because of the dust raised.

Mr. Atkinson replied that short circuits were bad, but there was no reason why the construction should not be done as well in England as in France. His firm had constructed in England a large number of metallurgical furnaces with the same system of recuperation, and the results which were being obtained from these furnaces as regards output and fuel consumption were analogous to those obtained with similar furnaces installed in France. With regard to the American coals, he would like to ask Mr. Frink, who was present, to reply if he would be so good.

Mr. R. L. Frink, replying to Mr. Atkinson concerning the efficiency of the Chapman agitator as related to various American coals and other types of producers, said this agitator type of producer had been worked on American coals of composition varying from volatile matter ranging from 18 per cent. to 46 per cent., and ash content ranging from 6 per cent. to 18 per cent. The character of the coal did not materially affect the efficiency of the agitator, although it was necessary to adjust its speed of rotation, as also its depth in the fuel bed. It was true, too, that for the different kinds of coal it was necessary to change the relative quantities of steam and air introduced into the producer in order that a uniform and desired composition of gas should be produced.

In one factory, having no fewer than six different types of producers, three, namely, one fully automatic, one semi-automatic, and one hand poked, were changed and Chapman agitators were applied. It was found that by lowering the steam pressure and reducing the speed of the agitator, little difficulty was experienced in overcoming the entrainment of dust in the flow of gas from the producer; this in some cases could also be corrected, depending upon the character of coal, by altering the depth of the stirring bar, as also the speed of its rotation in the fuel bed. The amount of dust carried by the gas from the producer was found to be in a measure proportionate to the velocity and pressure in mains or necks, and it was found desirable to maintain this pressure lower than was required in other types of producers.

He would add that, of the six types of producers that existed in this factory, substantially all of them had since been altered and the Chapman agitator applied.

The principal advantage he had found in using the Chapman agitator was its prevention of hot zones and holes, whereby an excess of air was permitted to flow through the fuel bed and effect a partial combustion of the evolved gas in the upper portion of the producers, whilst local hot zones produced excessively hard clinker. He believed that because of these results, this form of agitation had proved satisfactory for glass-making purposes.

One member of the audience desired to correct an impression as to the Talbot stirrer. At present it had two arms. The older type with two or three arms on a long stalk had been discarded. It was an open question whether agitators were required at all. He inquired if there were any Chapman agitators working on highly coking coals. The Talbot stirrer was preferable, as it broke these up. At Cargo Fleet the composition of the gas used was:—

CO_2	7·93
CO	20·93
H	13·97
CH_4	2·94
N	54·23
	100·00

He desired to know whether any information was available regarding the use of Chapman agitators with Durham fuels, which were highly coking.

Mr. Atkinson replied that there were no Chapman agitators working on Durham coking coals at present, but there were a large number of agitators at work in America with coals of very high coking qualities at least equal to Durham coals.

Mr. T. W. Ferry inquired for figures as to the size of grate and of producer, and the consumption of coke for twelve or twenty-four hours.

Mr. S. N. Jenkinson observed that the cracking of glass pots was not due to local cooling in glass furnaces, but to local heating.

Mr. Atkinson said he would be glad to give members of the Society happening to visit Paris the opportunity of seeing the Stein pot furnaces in operation there.

Mr. Atkinson (*communicated*) said that in further reference to questions raised in the discussion, especially in regard to the efficiency of the furnace, he had received actual data from Messrs. Houdaille and Triquet, which he could not do better than quote as received:—

"The consumption of coal is 2500 kg. for a furnace of 12 pots, each containing 450 kg., that is, 5400 kg. of melted glass. It is obvious that in working it is impossible to empty the pots completely, and it may be reckoned that the quantity of glass which can be worked is from 380 to 400 kg. per pot. There always remains, as a matter of fact, about 50 kg. of glass at the bottom of the pots before recharging. However, this proportion depends on the size of the pots. It is evident that in the same furnace it is possible to use pots of greater length whilst keeping to the same width, and the weight of melted glass might thus be increased.

“Experience has shown, in the majority of cases, that in the same furnace the contents of a pot containing 500 kg. may be worked as quickly as those of a pot placed beside it in the furnace containing only 400 kg. The reason is that the quantity of heat employed for melting is proportionate to the surface area of the pot. If, theoretically, the proportion does not remain the same, seeing that the surface varies as the square, whilst the weight of the glass varies as the cube—in practice we have always remarked that the contents of large pots melt as quickly as those of small ones.

“At Choisy we have two furnaces running, one with pots of 600 kg. and the other with pots of 450 kg. Now the contents of the pots of 600 kg. melt as rapidly as the contents of those of 450 kg.

“Replying to Mr. Atkinson's questions, we would say that:—

“(1) The temperature inside the furnace, taken in the gaseous atmosphere directly surrounding the pots, varies from 1450° to 1600°.

“(2) The temperature of the glass when working varies according to the composition of the glass. Crystal glass has generally a temperature of 800° to 850°. Ordinary white glass has a temperature of 850° to 900°.

“(3) The white glass used when the test was made had the following composition (before charging):

Silica	100
Lime	20
Soda	35
Nitrate of Soda	5
Colouring matter	X

With this glass we make lamp chimneys and tube for makers of articles made with a blowpipe. We also make laboratory articles of neutral glass, and this latter glass is a little longer melting, as it is much harder.

“We may add that our second furnace, where we use pots of 600 kg., the number of pots being also 12, the diameter of the furnace being greater, the consumption of fuel is also greater, and reaches 3000 to 3200 kg. per twenty-four hours.

"We have, therefore, 600 × 12 = 7200 kg. of melted glass for a fuel consumption of 3200 kg., that is, 440 per 1000.

"In the first furnace, of 12 pots of 450 kg. for 5400 kg. of melted glass, the fuel consumption comes to 462 per 1000.

"The results are therefore very much the same in the two furnaces, but would be slightly better in the furnace with pots of 600 kg."

Messrs. Stein & Atkinson,
Victoria Street, London, S.W.1

XVIII.—*The Glass Industry of North America.*

By W. E. S. Turner.

INTRODUCTORY.

The following notes are written after a visit to a large number of factories, more than seventy in number, scattered over a wide area and engaged in the manufacture of a great diversity of products, including optical glass, table ware, illumination and general domestic glass, electric insulators, scientific apparatus made both at the furnace and at the lamp, electric bulbs, window and plate glass, and bottles of all kinds. It is much less of a duty than a pleasure that my warmest acknowledgment should be made of the very kind reception everywhere accorded both to myself and to my travelling companion, Mr. J. Connolly, who not only shared with me whatever discomforts of travel there were incidental to a lengthy tour undertaken in a comparatively short period of time, but enjoyed with me also the cordial, even at times affectionate, greetings of our American members and friends.

Whatever value there may be attached to this report, one of its main intentions is to awaken in members both the desire and the intention to go out to see for themselves something of the progress that is being made in America, and by the interchange of ideas and the formation of personal friendships to assist in promoting that sense of good fellowship and co-operation between the two countries which is so greatly to be desired.

I. LOCATION OF THE INDUSTRY.

The American glass industry has now become diffused over a wide area. As yet, with a single exception (in Alberta), it is confined in Canada to the region of the great lakes, namely, at Montreal, Toronto, Hamilton, Thorold, and Wallaceburg. In the United States it has spread gradually into a large number of States. Only two of the New England States, namely, Massachusetts and Rhode Island, have any glass industries, but below these all the States east of the Mississippi River, except Georgia, Alabama, North Carolina, and Kentucky, have some representative firm of the industry within their borders, whilst the Mississippi no longer forms an industrial dividing line, for a number of States west of it have important glass factories.

Although the earliest glass works had no relation to the fuel-producing States, the development of the industry in America has followed very largely the discovery of natural gas wells. Hence the importance of Pennsylvania and West Virginia, and, to a less degree, of Ohio and Indiana, as centres of the industry. Twenty or thirty years ago it was quite customary for small towns to offer, not only free sites for glass works, but also free natural gas, and sometimes, also, freedom from taxation for a period of years. Pennsylvania has now, however, been largely drained of her natural gas, whilst in Ohio and Indiana the supply is much less abundant, and so apt to fail in the winter that gas producers are being widely installed. West Virginia is more fortunate, and in recent years has attracted a large number of glass firms. Even here the supply of gas is recognised as not inexhaustible, and more than one attempt has been made by the State Legislature to prevent its distribution to other States through the long pipe lines, many of which run for hundreds of miles. It is also because of the discovery of natural gas that the glass industry has spread westwards and southwards into States such as Arkansas, Oklahoma, Texas, and Louisiana in recent years.

To some extent, a segregation of the different branches of the industry appears from a study of the various factories. It is quite impossible to draw a hard and fast line, but this much may be said, namely, that very fine artistic glass is made in the State of New York; most of the optical glass produced during the war has likewise come from this State; lamp-blown and graduated scientific apparatus making is largely concentrated in the southern portion of New Jersey; and the bulk of the window and plate glass is made in Pennsylvania and West Virginia. Illuminating and general domestic glassware is a widespread industry. Bottles are made everywhere; even the Pacific Coast is already providing a home for several factories.

Widespread Use of Glass in America.

In this very brief introductory section, attention may be directed to the far greater and more numerous uses for glass which have been found in America than in the United Kingdom. Plate glass has considerable vogue for purposes other than windows. Thus, it is used not infrequently to form the inner lining of passenger lifts in hotels, it appears as a covering sheet on many office desks and tables, and is a very clean and pleasing material for small shelves in bathrooms and lavatories. Thick opal sheet glass forms the tops of the tables in many popular restaurants and the wainscoting of bathrooms. In the bathrooms of hotels and houses, the towel bars are almost always of glass, which is drawn into rods of different thicknesses and cut into various lengths for the purpose. A thick opal glass bar likewise provides the usual handle by the aid of which one rises from the bath. Packers' goods, such as preserves and jellies, are usually put up in common pressed glass tumblers, the production of which is enormous, one firm alone making 4,000,000 per week. Insulators for telephone and telegraph wires are almost everywhere of common green glass, and the enormous use of telephones in America will indicate the great production required of these articles. Two other recent developments may be mentioned, namely, the manufacture of glass oven dishes for baking and cooking, a line which has been taken up by several firms and found almost immediate favour with the public as a substitute both for metal and pottery; and glass coffins, made by a huge power-driven press.

II. THE RAW MATERIALS FOR GLASS MAKING.

Glass Sands.—Much has already been written in regard to the excellence of the glass sands in the United States, and in this respect, at least, the country enjoys enormous advantages over our own. The sands most widely used are the Ottawa sand from Illinois and that from Berkeley Springs, West Virginia. The former is used in the Canadian factories, in Indiana, Ohio, and also in the north of New York State. Berkeley Springs sand finds its market mainly in Pennsylvania and West Virginia. The Rockwood deposit, Michigan, does not appear to have found much favour, for, whilst pockets of great purity are found, it is charged with being frequently variable in composition and having too much calcareous bind. Berkshire sand has no very extensive use. South New Jersey, which over many square miles has a fine, sandy soil, produces excellent sand for the large industry within its borders. Besides these deposits, consignments from the same sources as those from which Britain draws have often found their way to America. Fontainebleau sand was carried to Montreal before the War, whilst shipments of Belgian sand at $2·80 per ton have already been resumed to glassworks in Brooklyn, New York.

Soda Ash.—For the bulk of the glass made in America, only two other main ingredients are employed, namely, soda ash and lime. Alumina in any form appears as yet to be scarcely used in the bulk of the tank-made glass.

The soda ash differs in no perceptible way from ours, but a dense variety is used with great advantage.

Salt-cake.—Salt-cake appears to be used only for window glass, sometimes mixed with soda ash, but, so far as the writer's experience went, usually alone, powdered coal being added in order to speed up its decomposition.

Lime.—Lime is nearly always employed in the burnt condition. In one window-glass factory limestone chippings found favour, but, in general, burnt lime is the form added to the batch.

In a number of cases, however, the lime is not pure lime, that is to say, it is not pure calcium oxide, but burnt dolomite containing a definite percentage of magnesia. The latter material has some advantages in extending the working range of a lime glass, and especially is this substance being studied in one or two factories employing a feeding device to charge glass-making machines.

Concerning other glass-making materials, such as are required for pot-made ware, no comment is called for.

Glass Decolorisers.—The subject of decolorising glass has been recognised, however, as of supreme importance. Far more white glass is now made from tanks than green. Indeed, green bottle glass appears to be going out of favour. Not only white bottles, but chemical ware, glass tubing, tumblers, lamp chimneys and globes, oven ware, and electric light bulbs (non-lead) are amongst the objects made from tank furnaces, whilst at one factory blanks for cutting purposes, of really brilliant semi-crystal (non-lead), were turned out in large quantity.

Undoubtedly the secret of good colour is the use of pure materials. The finishing touch, however, requires that a suitable decoloriser shall be found and its use correctly regulated. Much more progress has been made by the United States industry than in Britain or anywhere else. The development of tank furnaces suitable for colourless glass has called for this investigation, and the results speak for themselves.

Manganese dioxide is quite a good decoloriser provided oxidising conditions can be maintained. This can only be accomplished satisfactorily in a closed pot and in the presence of nitre. The tank furnace prescribes reducing conditions, and for this a decoloriser capable of action under these conditions must be sought. For this purpose, the element selenium fulfils the requirements quite well. A number of patent decolorisers have been built up with this substance as the essential constituent; Be-Ka, a German preparation made quite a number of years ago, gives the clue to the composition of the later ones. They consist usually of a high percentage of white arsenic, a definite amount of either the element selenium or one of its salts, which becomes reduced to selenium in the furnace, and a very small proportion of either cobalt oxide itself or "powder blue." The amount of this decoloriser required is very small. It is added to the batch, and in well-regulated factories samples of the glass are withdrawn every few hours during the day, and the amount of decoloriser, in succeeding batch charges, varied according to the observations made. Just as manganese is unsatisfactory under reducing conditions in the furnace, so selenium does not exercise any decolorising function in the presence of oxidising conditions. Nitre, for example, must be absent from the batch mixture, and consequently for lead glass manganese must still be employed.

III. The Mixing of Batch.

American glass manufacturers have almost everywhere learned not only the value, but also the absolute necessity of thorough mixing by mechanical means. Even comparatively small factories had their batch-mixing systems, consisting of weighing machine, mixer, elevator, and batch storage hopper. Only at one bottle works, so far as the writer ascertained, was batch still mixed by hand, and even there it was the intention of the management to instal machinery for the purpose.

These remarks on the widespread use of automatic mixing plant apply with less force to the smaller pot-furnace works. Not unnaturally, where a number of special glasses are being made, no single mixer could meet the requirements of the works, and a set might be expensive both to instal and to work. But most pot-furnace works making large numbers of any one article mixed the batch by machine. In one factory the cube mixer was employed, consisting of a cubical box with axles fixed to the diagonally opposite corners, an arrangement not unknown in our own country; in another, a cylindrical mixer with rotating paddles was given preference to any other type, whilst in several works the Smith mixer, referred to below, was installed.

The methods of mixing employed differed in the degree to which the details were elaborated, but in general they fell into two types. In the first, at work in eight of the tank glass factories visited, the raw materials for the batch are stored in a series of large cylinders, either of cement, concrete, or iron, arranged in a line and built at such a height above the ground-level that the mixing truck, with operator standing on its base, can pass readily along on rails below them. The cylinders may have a capacity of several hundred tons, and are charged direct from the railway wagons, which usually are brought on to a siding parallel to the row of hoppers. The motor truck carried a combination of weighing machine and mixer. From the bottom of each of the hoppers, as required, material was withdrawn until the indicator on the machine showed the correct quantity, and as the truck moved along, a separate motor rotated the mixer. The mixture was then dropped through a grating in the floor and fell on to a conveyor belt carrying the batch to the batch hoppers, one of which was fixed at a convenient height above the dog house of each furnace. From these hoppers, which usually consisted of an iron cylinder with cone-shaped bottom and a sleeve descending to within about 2 feet of the top of the dog house, batch was run out at fixed intervals, usually every twenty minutes, at the time when the regenerators were reversed, by opening a valve in the sleeve.

Batch mixers of the type referred to are made both by the Stevens-Adamson Co., Aurora, Illinois, and the Link Belt Co., Indianapolis. The last-named mixer consists of a rotary steel drum 6 feet in diameter and 2 feet 6 inches wide, mounted on a weighing scale, with a beam capable of weighing six different batch materials independently. A steel-frame truck carries the mixer and weighing beam, and, in addition, a motor for rotating the mixing drum at nine revolutions per minute, and a second motor for driving the truck. The drum is designed to handle 35 cubic feet of batch, this volume representing one-half the total drum capacity.

With one of these mixers and the system described it is possible, as at the Libbey Owens Window Glass Co., Charleston, for one operator to handle all the batch required for six large tank furnaces.

The second system, in widespread use, did not necessarily involve the use of the storage cylinders for raw materials; indeed, usually these did not form part of the system. Sand, lime, and soda ash in the desired order were weighed in turn into a truck by means of a platform weighing machine fitted with a secret scale * which could be set by the factory manager. From the truck, the materials were tipped into a shallow box provided with a cover and a spout, and next raised and poured into a mixer, which, in this system, was almost invariably the Smith mixer, consisting of a short horizontal cylinder with truncated conical ends. Into the opening in one end the batch materials are poured, and emptied through the other after being mixed, either on to a dump on the floor or, usually, down a chute to an elevator, and thence to the batch hoppers already referred to.

This latter system was stated by its users to have given satisfaction, and no difficulty was incurred in adding and thoroughly incorporating the decoloriser with the main batch in the mixer. The mixer is made by the T. L. Smith Co., Milwaukee, Wisconsin.

Some factories had also found the advantage of breaking up the cullet employed, storing it as carefully as the raw materials, and of adding it to the batch in a perfectly definite proportion. This practice, though not very widespread, was followed by works not only making bottles, but also table ware, window glass, and electric bulbs. The crushing was done by chilled steel rollers, and a magnetic separator for any traces of metallic iron from the rollers was also, in some cases, in use.

IV. Glass Melting Furnaces.

Quite a number of different types of furnace were encountered, using coal, oil, natural gas, and producer gas fuels.

As already pointed out, natural gas is failing in many of the large glass-making districts. Whenever it can be obtained at a reasonable price it has many advantages. Obviously, it avoids the troubles which may beset the working of producers, it is readily controlled, is clean, and has a very high calorific value, namely, 1000—1100 B.T.U. per cubic foot, against the 150 B.T.U. of ordinary producer gas. Owing to its great heating value, it is very valuable in melting the resistance glass which forms the basis of oven ware. There is a limit to its economical use, however. In Charleston, West Virginia, the ruling price was 15 cents per 1000 cubic feet, and probably similar rates held in other towns of that State. Near Buffalo, New York State, and at places in Penn-

---

* Such scales can be purchased from the scale manufacturers in this country; or, in the States, from firms such as the Buffalo Scale Co., Buffalo, N.Y., or the Fairbanks Scale Co.

sylvania, the rate had reached 35 cents, at which point gas producers were found to be more economical. Not only is there the actual difference in the price of gas, but the further important consideration that for a period, which may be two months in duration, during winter the pressure of the natural gas either falls so low as to make it difficult to maintain the furnaces in operation, or fails altogether; and in such cases it becomes necessary to have either oil or a set of producers as a stand-by, in which case a considerable amount of capital is lying idle.

Types of Gas Producer.

Of the producer plants to be seen, some were far from modern; but, on the other hand, especially in the larger works, batteries of up-to-date producers were installed feeding into a main flue. Three types of producer in particular appear to compete for favour in new installations, namely, the Morgan, provided with a mechanical stoker to maintain a compact fuel bed; the Chapman, with a rotating agitator, raking and keeping level the hot fuel; and the R. D. Wood, provided both with a mechanical poker curved away from the vertical and made to gyrate so as to stir all parts of the fuel, and with a dust trap in order to clean the gas.

The Chapman agitator was also in operation as an attachment to existing brick-built producer plants. In one well-equipped factory, a Morgan producer was fitted with an automatic feeder and an automatic weigher which registered each 100 lb. of coal delivered in the producer by means of a hopper. This device, it seemed to the writer, represented the most serious attempt to obtain precise control of the amount of coal consumed on a glass plant. Coal crushed to a fairly definite size was required for this device, and a coal-crushing plant, from which the fuel was removed by a conveyor, made the plant complete.

By-product Recovery Plant.—Particular mention must also be made of the successful use at one large plant of producer gas made by the Linn by-product recovery system. The plant was operated by an independent firm on a site adjacent to the glass works, the gas being washed for the purpose of recovering tar oil and ammonia. Although the calorific value of the resulting gas, namely, 120 B.T.U., is less than that of untreated producer gas, it appeared to be perfectly successful in operating a large regenerative tank furnace having a daily output of nearly 60 tons.

The Frink Regulator.—Two other devices intended to assist in the control of gas-heated tank furnaces must also be mentioned, and are worthy of the serious attention of all glass manufacturers using producer gas. Of the two, the first, namely, the draught recorder, registering automatically each reversal of the regenerators, is not unknown in this country. The second device is newer. It is an attempt to control the flow of producer gas from the producer flue to the regenerator; in other words, it is intended to make it possible to deliver a definite and constant volume of gas continuously to the furnace. Two forms are already on the market. One, made by the Frink Laboratories, Lancaster, Ohio, has a narrow pipe connecting the gas in the producer flue to gas imprisoned above oil in a small gasometer. If the pressure of the gas in the producer flue varies, that in the gasometer rises or falls in conjunction, as also does the level of the liquid in the latter. Contact between two metal surfaces is made or broken, according to the rise or fall of the gasometer liquid, and, in turn, a motor, actuated by the current flowing between the contact, raises or lowers the damper in the flue, admitting gas in the one case or reducing its amount in the other. The device was seen in actual operation at a glass works where an attempt was being made to remove slight imperfections in its operation.

The Chowning Regulator.—The other regulator is made by the Chowning Regulator Corporation, Corning, N.Y., and is also installed in more than one large glass works. It attempts to maintain not only constant pressure in the gas main from the producers, but also operates on the steam and air injected, so that the latter are also regulated in amount. Reports from actual plants showed that a saving of 3—5 per cent. was effected on the coal passing directly into the producers, whilst a further saving of 11—15 per cent. was made on the steam injected (cp. p. 199).

Direct Coal Firing.—In the southern part of New Jersey, direct coal firing is still a very common practice, especially for pot furnaces, but the question of economy in fuel is becoming now a much more important factor than formerly with the manufacturer, and outside this district direct firing is practically unknown.

For purposes of comment, it will be convenient to discuss furnaces under the headings of tank furnaces, day tanks, and pot furnaces.

Tank Furnaces.

Many different types of glass are now produced in them, including white and coloured bottles, electric light bulbs (non-lead), lamp chimneys, tumblers, globes, chemical ware and tubing, oven ware, and some table ware.

The capacity of a tank furnace is rated in America on its daily output and never on its dead-weight capacity, and as high production is an insistent demand of the American manufacturer, he cannot see the sense of describing a furnace as a 200- or 300-ton tank when it merely holds that quantity.

Now the output from a furnace depends on the size and power of the melting end and on the rate at which the metal melted can be worked out into useful ware. The second factor is partly a question of size of the article made, partly one of the use of machinery. In regard to the former, American practice regards the size of the melting end as that dominating the capacity. The working end can be varied to suit particular needs, and, indeed, considerable variation is found. As a standard practice, the Owens Bottle Co. suggests a melting area of 17 square feet per ton of glass melted daily. At a number of works this power is easily exceeded. Thus, at one, the average output corresponded to 1 ton for each 11 square feet, and at two, of which special note was made, the melting power was as high as 1 ton per 8 square feet.

In regard to depth, window-glass tanks practice appears to be different from that for other types of glass. Although the writer's inspection was confined to only four window-glass tanks, the depth there, and apparently in fairly general use, was as much as 5 feet. For most other glass, such as bottles, a standard appears to have been reached. Mr. H. L. Dixon, whose experience as a furnace builder in America is unique, has, after much experiment, settled on 3 feet 6 inches as the most suitable depth for the tank. Instances of tanks 3 feet, or even less, were found, but almost everywhere, whatever the length and breadth, the depth was 42 inches.

The following dimensions of the melting sections of some tank furnaces seen in operation, together with output where ascertainable, will illustrate the foregoing remarks:—

Length.	Breadth.	Depth.	Daily output.	Mode of operation.
34′	24′	2′ 9″	50 tons	Owen's
32′	20′	2′ 6″	—	Owen's
20′	14′	—	15—18 tons	Hand
20′	16′	—	30—40 ,,	S. Automatic. Aut. Feed
25′	16′	—	—	Owen's
45′	20′	—	80 tons	—
32′	16′	3′ 6″	105—120 per wk.	Semi-Aut.
38′	25′	3′ 6″	—	,,
14′	12′	3′ 8″	24 tons	,,
32′	14′	4′ 0″	60 ,,	,,
12′	10′	3′ 6″	18 ,,	,,
32′	20′	3′ 6″	57 ,,	Automatic feed
15′	10′	—	—	—

The furnaces only 10 feet wide were usually found to be too narrow and the regenerators became overheated. In the majority of cases it will be seen that the breadth is very roughly two-thirds of the length of the melting end.

The size of the working end was more or less a matter of convenience, depending partly on the means adopted to work out the metal. The tenth furnace on the list above had a working end the internal dimensions of which were 16 feet across the bridge and 18 feet from the bridge to the nose. This, however, represents an unusual example, although a furnace with a proportionately still longer working end is in operation.

The Dog House.—One other important section of the furnace must be referred to, namely, the dog house. This was an adjunct to all furnaces seen except at one works, where two small furnaces had been built back to back so close that use of a dog house was difficult. The advantage of charging into the dog house can be strongly recommended to all manufacturers.

Life of Tank Blocks.—In America, the length of life of a tank furnace is considerably greater than in England. When a tank furnace is started at the end of the summer, it is expected to run without repairs, under normal conditions, until the summer vacation in the year following. Even then no special means are adopted to preserve the life of the tank blocks; that is to say, the top course of blocks, even, is expected to last at least eleven to twelve months. Two causes contribute to this increased life. In the first place, the batch mixture contains soda ash almost invariably as the source of alkali. At a window-glass plant using salt-cake and soda-ash mixture, the top course usually had a life of six months only. Further, the proportion of lime in the average American batch is distinctly lower than in some of the high lime mixtures for common bottles in England. Finally, what appears to be very effective is the employment of cooling devices to keep the exterior of the blocks cool.

Cooling Devices.—Cooling methods are in fairly general use, sometimes for the whole of the side blocks, in others for the top course only. In one case, the air from the compressor was passed through a cold-water spray so that it entered the glasshouse at a temperature of about 10° F. below the room temperature, this being more effective, not only in cooling the blocks, but also in maintaining a comfortable temperature in the furnace-room itself. Usually a series of pipes from the fan was directed against the blocks in the same manner that cooling pipes were fixed round the furnace for the benefit of the workers and the machines.

A water system has also been introduced, and one engineering firm, the Blaw Knox Engineering Co., makes a speciality of such devices. Essentially, the method consists in bolting a series of iron plates to the face of the furnace and causing water to flow down them continuously from a sprinkler. Such devices are in operation in several glass works with good results. At times when the side of a furnace shows local wear with the threat of a break-through, it is quite a common practice to apply an iron plate with water cooling to it in order to make it possible to continue in operation until the summer vacation.

Water cooling of the working end was also found to be adopted in several works in New Jersey, and was not seen anywhere else. It appeared to be very effective, although where the take-away was not kept clean the water flowed over on the standing places of the workers.

Cooling of the tongue in the gas ports was also in use in several works. Insertion of a small water-cooled box has been tried, but experience does not appear sufficiently ripe to decide as to the reality of advantage of such a system. Usually, two narrow flues or air boxes are built through the cross-section of the port so as to cool the tongue by air.

Pot Furnaces.

About twenty years ago, according to Mr. H. L. Dixon, there was a craze in America for recuperative furnaces, but the installations made were attended by such disastrous results that the pendulum of opinion swung right back in favour of the regenerative system for pot furnaces. To such an extent is this so, that only in a single instance was a set of recuperators found attached to a furnace, and this was in a special case where it was only desired to keep a pot of glass sufficiently hot to work after being filled from a melting furnace.

The pot furnaces seen were of different shapes, rectangular, oval, and round. The first shape was in use in plate-glass works, the oval in one or two table-glass and illuminating glass factories, but in the majority of cases the round type was preferred. The rectangular and oval were all regenerative furnaces, in all cases but one gas-fired, in the remaining example, oil, injected by steam, was supplied to two burners at the side of the flue or port delivering regenerated air, about 2 feet above the siege. At every reversal, which occurred every twenty minutes, it was necessary to extinguish one set of burners and light the others. This furnace was worked for only one shift per day, and it was stated that it could be relied on without fail to melt glass overnight and have it ready for working at a fixed time in the morning.

In regard to the regenerative pot furnaces, the writer was informed at one very well-managed works where the furnaces were largely engaged on melting glass for electric bulbs that the coal consumption (through producers) was only 50 per cent. of the weight of glass melted. This statement was also made, independently, by Mr. H. L. Dixon in regard to the works referred to, and it was further stated that the furnaces had been in continuous operation, without any but minor repairs, for four years, whilst a set at another works had been running for seven years. The H. L. Dixon Co., Roslyn, Pa, was also prepared to erect regenerative pot furnaces to hold sixteen pots, each in an arch of 48 inches, and to work them with a coal consumption of 8 tons per day. Except in special cases mentioned, the firing was done through slits or ports in the floor, the flame sweeping over the crown and down a corresponding set of flues.

It may be remarked, in passing, that the walling in of the regenerators seen was not infrequently defective, the red glow of the interior being visible through cracks or thin places in the walls.

Already in this report the glass industry in New Jersey has been mentioned as having special features. In only one works was there seen a gas-fired pot furnace, all others being of the French deep eye, coal-fired type.

One or two special modes of firing were noted. In two furnaces, an oil burner was fixed in the position occupied by the former direct-fired furnaces, and the flame directed upwards through the eye, the temperature attained being ample for the purpose of melting lead-containing glass.

In another variation, a Maxon Premix burner, made by the Maxon Premix Burner Co., Muncie, Indiana, in which natural gas is burnt with an automatically regulated quantity of air, was fixed so that the flame issued through the eye.

Day Tanks.

Day tanks are quite commonly met with in America. In one large glass bottle works, operated largely by hand labour, much of the small ware was made from day tanks, the argument advanced being that it was possible to maintain a better colour in the glass than with a continuous tank. Whatever truth there may have been in this view at one time, it no longer holds good.

Usually, day tanks were employed for special purposes, such as melting resistance glass in comparatively small quantities. In two such cases, Maxon Premix burners, with natural gas, giving a very hot flame, provided the means of heating.

V. Annealing Processes.

During the first portion of the tour, extending over a wide area, the writer was impressed with the care taken to avoid draughts in the lehrs. Later on, many old pan lehrs with open ends were seen, in which there was great room for improvement.

Belt lehrs were common, although, outside the Owen's plants, by no means general. In the more progressive factories, belt lehrs were to be found in operation as a rule, and the entrance to the lehr was kept closed, the bottles being introduced either through hinged flaps or doors, or through the side of the lehr, the former being suited to transference by hand, the latter automatically on a conveyor belt.

A simple form of self-closing door was obtained by casting it with a heavy bottom and hanging it on a horizontal axis. The goods were introduced by pushing against the top of the door, and when the carrying iron was withdrawn the door automatically resumed its vertical position. In another method, fairly common, opening the door was accomplished by the taker-in pressing a foot lever.

Automatic Bottle Conveyors.—Automatic transference of bottles was general in the Owen's plants. The standard device was one attached to a lehr in which the bottle carriers returned on a track at the side of and parallel to the lehr. The carrier consisted of an iron bar containing sufficient holes to give the closest possible packing to the bottles arranged side by side, neck downwards, in them. The bar began its journey at right angles to the front end of the lehr, with its first hole below a hopper or funnel, down which each bottle in turn dropped neck downwards after ejection from the machine.

After a bottle had fallen into position in the first hole, a device, carefully timed to the bottle machine, pushed the bar one space along ready for the reception of another bottle. By the time all the spaces were filled, the bar had been pushed into the lehr through the side, but not yet on to the belt which carried it forward. Transference to the belt was accomplished by a ram, accurately timed, which now thrust the bar forward to begin its travel down the lehr. While the bar was waiting partly filled, a flame under the section of it already within the lehr kept the bottles it carried from getting chilled. The bars were pushed up close to one another in the lehr, and very close packing was thereby obtained. Various other devices are in operation in connection with the Owen's machine suited to the particular lay-out of the factory.

Of the several devices seen for the transference of bottles to lehrs, probably the simplest and the one most capable of general use consisted of two conveyor belts running at right angles, the first from the machine, the second across and level with the front part of the continuous belt of the lehr itself. In order to transfer the bottles from the first to the second belt, a rotating iron disc, with a protecting gutter to guide the bottles, occupied the angle between the two, the levels of the belts and the table being carefully adjusted. A stop in the lehr at the side opposite to that of entry caused the bottles to line up in a row on the transverse conveyor belt, when a ram pushed them on to the lehr belt.

Muffle Lehrs.—A scientifically constructed lehr, in which the gradation of temperature can be adjusted to the particular ware to be annealed, is still lacking in America. Attempts, however, to obviate the necessity of cleaning glassware after passage through the lehr have been successful as the result of the introduction of muffle lehrs. There are several types in use, such as those made by the Amsler-Morton Co., Farmers Bank Buildings, Pittsburgh, and by the Simplex Engineering Co., Washington, Pa. In principle, they consist of three sections. The heat may be applied under the bottom of the first section, passing up and round the walls, through a hole leading to the top of the second section, down the walls and underneath to the third section, where the direction of flow is as in the first. The gas then passes to a flue.

In another type the burners supply heat at the top of the first muffle section, and the direction of flow is the opposite of that already described.

These muffle lehrs are finding their way into quite a number of works manufacturing table ware and illuminating ware, and, in general, their users appear satisfied that they are advantageous.

Kiln Annealing.—Annealing in kilns was not seen in a single bottle works visited, but was in extensive use as an adjacent to lehr annealing in the large factories making table and illuminating ware, the process being adopted with large or heavy articles. Gas-fired muffle kilns were employed, the articles which had already passed down the lehrs being packed inside the muffle on trays rising one tier above the other.

For hand-blown tumblers, a method in use in two or three factories consisted in placing the hot article in an iron box, the latter resting on a stand with a flat hood over it and a burner under it. The heat applied kept the tumblers from becoming chilled, and when full the box was carried and placed in the lehr.

The inspection of glassware for strain was quite commonly carried out in glass factories, not only on tableware, but even on electric bulbs and common glass bottles. In one factory making soda-lime-magnesia bulbs, 50 out of every 1000 bulbs were examined for strain as a check on the efficiency of annealing. Where technical assistance was available in the works, the strain viewer often took the form of the ordinary crossed Nicol prisms, but a very convenient form of apparatus, in which the analysing Nicol was replaced by parallel plates set at the polarising angle, was in use in bottle factories. The instrument, known as the scleroscope, is made by the Ensign Instrument Co., Chicago, and requires no technical knowledge to work it.

VI. Pyrometric Control.

Whilst it is an exceptional experience in our own country to find temperature indicators or recorders attached to glass furnaces, and even annealing furnaces, in the States it is unusual not to find them. True, there are some works in which the meaning of the records obtained seemed to have little significance, but for the most part the pyrometers were periodically checked, usually by arrangement with the instrument company, and did assist very materially in the control of the furnace. Thermo-couple pyrometers were almost universally employed, usually one at the melting end, the other at the working end, being let through the brickwork of the crown. The Fahrenheit scale of temperature is in general use, and on this scale the temperatures at the melting end were registered variously between 2300° and 2500°, and at the working end 2100° and 2200°.

Pyrometer control was also placed on lehrs. In a well-controlled window- and plate-glass factory, lehr records were taken in each case at four different points. The actual temperatures recorded in lehrs probably bore no close relationship to the upper annealing temperature of the glass undergoing treatment, for, whilst lehrs containing lime-soda goods were found to have a recorded temperature of 800—1100°, those containing large articles of lead glass were seldom cooler than 950°, and in some cases were as high as 1050°. In practice, of course, when once the most satisfactory annealing conditions have been discovered, the actual reading of the pyrometer matters less than the fact that it should be constant.

VII. The Manufacture of Bottles and Jars.

Hand-made Bottles.

Bottles are not all made by machinery in America, and one large works visited, as well as several smaller ones, was operated mainly by hand. This much is to be said, however, that the hand work is almost entirely confined to small ware of 6 oz. capacity and less.

In the hand shops, the writer was surprised at the density of labour to be seen at the working end of the furnaces. The usual American "shop" (corresponding to our "chair") consisted of seven men, of whom three are skilled, two being blowers and one the maker or finisher; and at one works no fewer than twelve "shops" were at work on one tank, by no means of large size. Such close packing of labour, with the blowers themselves working close up to the "ring" or "hole," can only be accomplished by very efficiently cooling the workmen by streams of air and by severely restricting their movements. Specialisation applies to hand work as to machine, and each operator in the "shop," as may be judged, performs but a fraction of the work involved. Close up to the furnace are the two blowers, provided each with a short blowing iron. At their right hand, as they stand with backs to the furnace, is a boy, who receives from each blower in turn the iron just used, cleans it from the adhering glass moil by one sweep of an iron forceps-like tool, and places it ready for fresh use. Immediately in front of the blowers as they turn round from the furnace is the marvering slab and the mould, and sitting in front of the marver, presiding over the mould, is a boy or girl (coloured unskilled labour being largely used), who cuts the moil, opens the mould, and places the bottles on an adjacent table. A fifth worker (unskilled) takes each of these bottles in turn, fits it into the punty, and hands the latter to the finisher, who puts on the neck, a seventh unskilled worker removing the finished article for annealing. The two blowers describe, in their movements, a triangular path of very limited dimensions, and by long habit learn to keep out of each other's way. The output of bottles from such a set of workers may be very considerable; in the case of 4-oz. bottles, as many as 55 gross per 8-hour shift.

Machine-made Bottles.

America is, above all, however, the home of the machine-made bottle and container. Machines for the purpose may be automatic or semi-automatic. The one really automatic bottle machine is the Owen's, all the others only being rendered automatic by combination with a distinct and separate device for feeding glass to the machine. When this is absent, they must be hand fed. It will be convenient to mention, in turn, the various types of machine seen in operation during the tour and to indicate which are suitable for automatic combinations.

The Owen's Machine.—The machine and its possibilities are so well known that little need be said of it. Its use in America is now widespread for bottles of various sizes between a small fraction of an ounce to 15 gallons. In one factory at Alton, Illinois, there are 27 machines, whilst the American Bottle Co.'s works at Newark had 17 in operation at the time of the writer's visit.* Most of the Owen's factories are models for those desiring to study labour-saving devices, and are very effectively run, whilst the output is enormous. One factory, using the 15-arm machine had an output of 80,000 fruit jars per machine per day, whilst of the very small bottles another factory had a daily record of actually packed bottles of about 1000 gross, the total number of good and faulty sometimes reaching 1400 gross per machine. For some types of small bottle, the writer was informed, the rate could reach 200 per minute.

The Owen's machine could scarcely be used economically for small ware were it not for the introduction of double and triple moulds, so that each 15-arm machine will make 30 or 45 bottles at each revolution.

The Graham or Owen's A.W. Machine.†—This machine represents a radical departure from the true Owen's type. It was introduced in order to avoid the use of the expensive rotating furnace, and as the moulds are not filled by suction, simplification of the machine becomes possible. On this machine there are 8 arms fed by a flowing device of the Brookes type. Whilst the machine is much less expensive than the Owen's, its productivity is not nearly so high. One unit was seen in operation side by side with a 10-arm Owen's machine, both engaged on the same type of bottle, of pint size. For the same twenty-four hour period, the output of finished, saleable goods was, in each case:—

Owen's, 10 arm	295 gross
Graham, 8 arm	132 ,,

For bottles which are fairly lightly blown, the products of this machine are not so satisfactory as those of the Owen's, whilst it is not intended for small ware. The machine is built for the more heavily made type of bottle, such as those for beverages.

The Hartford-Fairmont Wide Mouth Machine.—The Hartford-

---

* For list of Owen's machines then in operation in the United States, see article by Voll, "National Glass Budget," 1919, November 1st.

† British agents: The United Glass Manufacturers, Ltd., 195 Strand, London, W.C.2.

Fairmont Company, Hartford, Connecticut,* has two types of wide mouth machines already in operation, one, namely, a press and blow machine, for the production of wide mouth bottles, the other a press for the manufacture of tumblers. Both types were seen during the course of the writer's visit.

In either case, the machine has two tables, each of which really constitutes an independent unit. Presumably the two machines were built on one strong bed to form a complete machine, in order to absorb the output of the Hartford-Fairmont feeding device, to which reference is made later on.

The machine was seen in operation making wide mouth milk bottles, and for this purpose appears to be admirably suited, very high opinions of it being expressed by those firms using it. It is regarded as the most dangerous rival of the Owen's machine for this particular purpose. The speed of operation varied; at one works at the time of visit it was producing only 25 milk bottles per minute, but at another 32. It was stated to be much superior in action and trustworthiness to several other types of double-table machine, in which the two tables carry, one, the parison moulds, and the other the finishing moulds, especially when the latter type of machine was hand fed. On the Hartford-Fairmont machine the eight parison moulds and eight finishing moulds are all carried on a single table, there being an automatic transfer from the parison to the finishing mould.

The tumbler press was seen also in great activity, making about 34 per minute, or 15,000 per 8-hour shift. Four such machines were seen in operation at a single furnace, each operated by a separate Hartford-Fairmont feeder, and the work appeared to be proceeding very smoothly. The same company has in course of construction for commercial work a narrow mouth machine. The experimental machine has had a trial, which was reported on very favourably. Some months must elapse, however, before it becomes available for general use.

The O'Neill Machine.—Of the various types of double-table machine, this is one of the best known,† and has already come into operation in several works in this country. It was seen in quite a number of works, and reported favourably on. A new model with a transfer device from the parison to the finishing moulds, and a further transfer from the finishing moulds to a short conveyance, was seen in the O'Neill factory, from where it was about to be dispatched for installation in a glass works.

---

* British representatives: The British Hartford-Fairmont Syndicate, Ltd., Audrey House, Ely Place, London, E.C.1.

† British agents: Messrs. Ingersoll-Rand Company, 165, Queen Victoria Street, London, E.C.4.

A further type is a lighter built machine, called the "Prescription Machine," for the purpose of making smaller bottles, especially of the prescription type. This particular type was not seen by the writer connected to a feeding device, but was always hand fed. At one works it was producing 14—15 4-oz. bottles per minute, whilst at another making the same size bottle the gatherer was actually working at the rate of 18 per minute.

The W. J. Miller Machine.—These machines were also seen in operation at several works.*

The ordinary type, which is now fairly well known, needs no description. It has already been referred to in papers by Mr. W. M. McCauley † and by Mr. H. H. Pitt.‡

This firm makes a large number of different types of machine for general glass bottle manufacture. One of the double-table types has an automatic transfer and an automatic take-out. In another, which is just being put on to the market, but which was not seen in operation at a glass furnace, the double-table arrangement is done away with, and the parison and finishing moulds are arranged in two tiers round the central body of the machine, the parison mould being transferred to the finishing mould by means of the neck ring.

The Edward Miller Machines.—Two types were seen in use, namely, the 8-mould bottle machine, in which the parison and finishing moulds were arranged in two tiers. This particular machine was only in operation at one works, which held the complete patent rights in America. It was seen at work making bottles of 1 pint capacity for beverages, being fed by hand gathering, and producing 12 bottles per minutes.

In quite extensive use is the Edward Miller 8-mould tumbler press; it was seen in quite a number of places, and can work up to a rate of 22 tumblers per minute.§

The Lynch No-boy Machine.—Here again we have a machine which requires the service only of one operator, namely, the gatherer. It is a two-table machine with automatic transfer and take-out, the finished bottles being placed automatically on a short conveying belt, from which they can be transferred to the furnace either by hand or by a conveyor system. The machine was very highly spoken of. At one works a machine had been installed, and had worked with absolutely no hitch during the first week of its operation, and it appears to be giving satisfaction in all the works where it is installed. It is intended for the manufacture of narrow mouth bottles between the sizes of 4 and 32 oz., and within this range it can certainly be recommended.* Figures extracted from works records show that the machine had produced in nine hours 45 gross 2 dozen of 4-oz. flat bottles, and in the same time between 44 and 45 gross of 9-oz. jelly containers with screw cap.

---

* The Miller Glass Machinery Co., Swissvale, Pa.

† *J. Soc. Glass Tech.*, 1917, **1**, 203.

‡ *J. Soc. Glass. Tech.*, 1918, **2**, 19.

§ Edward Miller Machine Co., Columbus, Ohio.

The Cox Machine.†—Somewhat similar in type to the O'Neill and Miller are the Cox machines. They were seen in two forms, namely, a 5-mould bottle machine and a press machine for small wide-mouthed ware. These machines were in favour throughout the works in the south of New Jersey, although they were not seen elsewhere.

In addition to the above, a number of other types of machines, some designed and constructed for the particular works in which they were in operation, were seen. One of these machines was employed specially for pressing lids for wide mouth jars, and operated at the rate of 95 per minute. Another machine, not nearly so productive, used for small wide mouth ware, was of a static type, namely, the Olean, stated, however, to be no longer made. The Twentieth Century machine, made previously at Williamstown, New Jersey, is also said to have become obsolete and no longer made. It appears to have done excellent work, especially in the production of small bottles of 4 oz. and smaller capacity. It was seen in operation in several places; but, besides the gatherer, it required either two or three additional operators, and is therefore no longer recommended.

The chief criticisms levelled against the semi-automatic bottle machines which have hitherto been in operation are that the bed is far too light to withstand the continuous racket of an intermittent motion, and, secondly, in the case of air-driven machines, that trouble with the sticking of valves has been not infrequent. The last-named defect has, therefore, led constructors to make changes, so that the machine can be driven independently by power. One such machine was seen at the Glenshaw Glass Co., near Pittsburgh. The two sets of moulds were arranged in tiers round the body of the machine, so as to eliminate the necessity for two tables, and the transfer was effected by the ring mould. The machine was not only made compact in this way, but the power drive produced steady, if intermittent, motion. The machine is not yet on the market, but is receiving its final tests at the present time.

---

* Made by the Lynch Glass Machine Co., Anderson, Indiana. British agents: Messrs. W. A. Bailey & Co., Ltd., Audrey House, Ely Place, London, E.C.1.

† Made by the Cox Machine Co., Bridgeton, New Jersey.

Reference may also be made to the new W. J. Miller machine, in which the moulds are arranged in two tiers. This likewise has been equipped to be driven by power, whilst one or two other designers were found to be at work along similar lines.

One other criticism of existing machines may be made. The question is sometimes asked if light-blown bottles such as can be made by hand are produced by machines. So far as the writer's experience goes, none of the machines referred to makes a light bottle for beverages, or medicines, or for perfumes quite comparable with the article made by a highly skilled workman. The products of the Owen's machine are probably best in this respect, and some beautifully finished bottles were seen; but even the Owen's machine was seen in difficulty in trying to cope with the problem of making a lightly blown bottle. In general, the machines seen produced articles of uniform thickness and of uniform weight, but undoubtedly heavier than the hand blown.

If the lightly blown bottle is required, however, there seems nothing impossible about its achievement in view of the success of the Westlake machine in making articles so light as an electric bulb.

Automatic Production from Semi-automatic Bottle Machines.

The shortage of labour and the general desire for still further increased production have led to methods of automatic manufacture depending on the use of one of the semi-automatic machines previously described, coupled to some feeding device.

The feeding devices seen were of different types. For example, there is a machine made at Geneva, N.Y., which is intended to take the place of the gatherer. It is, in fact, a gathering machine which removes glass from the furnace by motions very similar to those which a man employs. It was stated by the superintendent of the works where it was seen, however, to be rather too complex for satisfactory work, and whilst it dispensed with a gatherer, it required close watching on the part of a mechanic, and therefore defeated the object of labour saving.

The other methods of feeding semi-automatic machines consisted in transferring the glass from the tank, either by the flowing device or by one in which glass is ladled out. The device seen most frequently in operation was a gravity feed of the Brookes flow type. The glass from the tank flowed into a boot, and then through a hole provided with a suitable bushing. Such a device is rather wasteful, since if the machine stops for any reason there is nothing to stop the flow.

Of the better types of feeding devices, the one most frequently seen was the Hartford-Fairmont, in which the glass is ladled out of the tank. In the five or six different works where the writer saw the device in operation it was spoken highly of, and appears to be the most satisfactory machine at present in extensive use.*

In several places it was working in conjunction with the Hartford-Fairmont bottle or tumbler machine. In other places it was coupled to the Lynch No-boy, the O'Neill, or to the Cox machines. For example, at one works it was arranged to feed three Cox machines simultaneously, the rate of output from the three machines being 38 pint bottles per minute, whilst on three machines for the production of small, screw-topped, wide mouth jars of about 1 oz. capacity, the rate was 60 per minute.

The writer was given to understand that the master patent for the Brookes flow feed, that is, for a feeding device in which there is a continuous flow of metal, expires in March, 1920, and after this date there would probably be a number of new devices brought on to the market.

One other feeding device was actually seen in operation, namely, the Tucker Reeves Feeder,† coupled to the Edward Miller Tumbler Press. In this device the glass which is left behind after the shears have severed the piece for the machine is shaped by a cup, which also pushes the metal up into the channel from which it flowed, and simultaneously applies a flame in order to re-heat the chilled portion. The device is much simpler in construction than the Hartford-Fairmont, but only one machine can be operated for each unit feeder. The tumbler press in question was turning out 22 tumblers per minute, and there were four machines in simultaneous operation at different parts of the furnace. At the time of the writer's visit, the British rights for the use of the feeder had not been disposed of.

Of other devices, not seen in operation but spoken well of, one may mention the W. J. Miller Feeder and the Howard Feeder, the latter in course of trial at the Berney-Bond Glass Co., Clarion, Pa.

---

* British agents: The British Hartford-Fairmont Syndicate, Ltd., Audrey House, Ely Place, London, E.C.1.

† The Federal Glass Co., Columbus, Ohio.

The general effect of the introduction of such feeding devices is to make it possible to operate the works with a very small number of workers. The conclusion must not be drawn, however, that such devices are in general operation in the States, since many factories were seen in which the semi-automatic machines were fed by hand gathering. Nevertheless, the installation of feeding devices is proceeding rapidly.

VIII. The Manufacture of Electric Light Bulbs.

The industry of electric light bulb manufacture is of great dimensions. The writer was informed that the three large electric lamp companies, who practically monopolise the output of electric lamps in America, had a yearly production of 200,000,000, and one is surprised, after witnessing the extensive sky signs in the various cities in the States and Canada, as well as the fact that the lighting of shop windows for advertising purposes continues long after the shop has been closed for business, that the number is not even larger.

At the present time both hand- and machine-operated methods are employed for the manufacture of bulbs themselves. The hand production was witnessed in several factories, and very large numbers are produced by this method. In contrast with our own method, the work is not done by individual workers, but by a shop consisting of two skilled workers—a gatherer and a blower—and a third worker who is unskilled. The intention is that the movements of each operator shall be restricted so as to make it possible to increase the output. It does not follow, however, at all that this system of standardising movements and operations succeeds in accomplishing the object aimed at. For example, the average output for two moves or turns, each of four and a-quarter to four and a-half hours' duration, was in the neighbourhood of 1200 to 1300. This, indeed, was the number given to the writer in more than one works both in Canada and the States. When one compares this figure with the output per operator in England, namely, 800 bulbs on the average per 8-hour shift, it will be realised that the American plan is not very successful. In our own country the worker gathers the glass, marvers it, and completes the blowing, and in speed he certainly holds the advantage.

In regard to machine operation, bulbs are produced on the semi-automatic Empire machine, to which reference has been made previously in this Society.*

The machine seen in operation had four arms. A 3-arm machine does not, apparently, keep the gatherer and the second operator sufficiently busy. The fourth arm makes work proceed better and more smoothly, and makes the machine more economical.

Hand-made bulbs appear to be destined to be replaced by the machine-made article, and for this the automatic Westlake machine is largely responsible. The latter was seen in operation with lead glass gathered by the machine from a pot or tank into which the glass had been ladled from a pot situated in a melting furnace. To the writer, however, the tank-made lime-soda-magnesia glass bulbs appear to be much more successful than the lead bulbs. The tank furnace seen in operation was operated by two machines with twelve arms, each having a daily capacity of 100,000 bulbs, although the rate of working at the time of visit was about 65,000 each. A machine with twenty-four arms was being arranged for trial having a capacity of 200,000 bulbs per day. There are, undoubtedly, somewhat greater difficulties in annealing and sealing lime glass in comparison with lead, but these difficulties are being overcome.

The Westlake machine is undoubtedly a wonderful contrivance, but it is probable it may have to give way to something simpler and equally effective.

IX. MANUFACTURE OF GLASS TUBING AND ROD.

Machinery for this particular operation is coming into use. One machine may be described as semi-automatic, since the cylinder must be gathered and marvered by hand, the final operation alone calling for the use of the machine. In the latter, the gathering iron is attached to a vertical cable passing over a pulley at the head of a tall tower, so that the tube is drawn out vertically.

Another machine has been devised for the production of glass rod by immersing a bait in the glass contained in a pot and drawing it vertically upwards at a uniform rate.

The Libbey Owens continuous tube-drawing machine was seen in three works making both lead glass and soda-lime glass tubing. In the latter case the machine was fed from a tank furnace. The opinion was expressed that the uniformity of bore of the tubing (up to approximately 1¼ inches) was very much in advance of hand-drawn tubing. The daily output of this large-sized tubing was stated to be 12,500 lb. In the case of lead glass, fed to the machine from a pot, as much as 120—140 feet of 5/32-inch diameter tubing per minute were continuously being drawn.

---

* See "Some Notes on American Methods and Practice in the Glass Industry," by H. H. Pitt, *J. Soc. Glass Tech.*, 1918, **2**, 19.

X. Chemical and Scientific Glassware.

A good deal of progress has been made in connection with the output of this class of glassware. As will already have been noticed from papers previously published in this Journal, a number of types of chemical glassware are being produced in the States, and several of them are of high quality, being superior to the best German pre-war products.

The Pyrex glassware has a large vogue, and appears to be in demand in most scientific institutions. Both the Pyrex and the Fry glass are not only chemically resistant, but also heat-resisting, and are made into baking dishes. So great is the demand for the Pyrex ware that a new factory is being set up in Texas to be devoted solely to this ware.

The production of chemical glassware is not confined to one district, but is distributed in several works at widely distant places.

The lampblown industry, however, is largely centred in Vineland, in the south of New Jersey. In this small city there are factories producing all kinds of lampblown ware, including all classes of syringes, thermometers of special types, complex pieces of apparatus with stopcocks of various design, including articles made up from very hard Pyrex glass; also there is a large output of graduated glassware, whilst fully automatic machines produce enormous numbers of flat- and round-bottomed tubes.

One method deserving of attention for the speeding up of the output of certain types of lampworking articles consists in the use of small sets of wheels on ball bearings, between which glass tubes and simple articles can be rotated, either for the purpose of preheating the ends or of annealing the ends after treatment. These sets of small wheels are supplied on every bench and driven from light shaftings by cords, which are connected to a pulley on the rotating wheels. Such a method makes it possible to economise the operator's time very considerably. In a number of respects America appears to be better provided with facilities for lampblown articles than we are at the present moment.

XI. Optical Glass.

Although the development of optical glass in America is of very recent date, attempts to introduce the industry were made quite a considerable time ago. Indeed, in the eighties of last century Mr. Macbeth, of the Macbeth Evans Company, began to make experiments on the production of optical glass, and some of his specimens are displayed in the offices of that company at Pittsburgh. Unfortunately, Mr. Macbeth was unable to get sufficient support from instrument makers to make it possible to commercialise the venture.

During the War, supplies of optical glass were forthcoming from a number of American sources, namely, from the Bausch and Lomb Co., Rochester, N.Y., the Spencer Lens Co., Buffalo and Hamburg, the Pittsburgh Plate Glass Co., Charleroi, Pa., the Keuffel and Esser Co., Hoboken, New York, and from special furnaces set up by the Bureau of Standards at its Pittsburgh station.

Messrs. Bausch and Lomb had been making preliminary experiments prior to 1914, but their real developments took place only after that date. In the case of all the other sources, no serious experiments prior to the outbreak of war appear to have been attempted. Although it is impossible in a report of this character to deal adequately with the developments that took place, one or two general remarks may be of interest. The first is that, with the exception of the Keuffel and Esser product, the whole output of optical glass made in America has been due to the efforts of the chemists and physicists who came from the Bureau of Standards and the Geophysical Laboratory, Washington, and with the hearty support of the firms named, set themselves energetically to work on the problem. Another very noteworthy feature of the work is that there has been no secrecy, and that we have witnessed what has not taken place in any European country, namely, the publication fully and freely of all the details of the work performed. The papers which have appeared on the subject in the *Journal of the American Ceramic Society* represent a very definite and valuable contribution to the subject.

Very interesting is the case of Mr. Carl W. Keuffel, of the firm of Keuffel and Esser. His firm is interested in the construction of surveying instruments, and he himself had no knowledge of glass making save that which he could get from books. In conjunction with an intelligent workman who had never seen a glass factory, he ultimately triumphed over many obstacles, and the writer was informed that some of the best boro-silicate glass made in America during the War came from the plant operated by Mr. Keuffel.

The future of the optical industry in America is not quite clear, and at the moment it appears that, with the exception of the Spencer Lens Co.'s plant, all the other factories will shut down. The work achieved, however, is a tribute, such as must also be paid in our own country, to the ability of trained scientific workers to enter a highly technical industry and make great advances. The value of the introduction of new blood into an industry is likewise illustrated.

XII. Refractory Materials.

The study of refractory materials is arousing much interest in America, and one or two notes may be of interest.

For example, in regard to tank blocks, the tendency seems to be towards a reduction in thickness. Indeed, in one or two works blocks of 8 inches thick only were in use, and confidently expected to last until the whole of the tank was put out for repair at the end of the year. This longer life of the side blocks in a tank furnace has been already referred to. It is obtained partly by the use of soda-ash as the method of introducing alkali and partly by the employment of cooling devices, either air or in some cases water.

In one special direction considerable progress has been made with glass pots. This is for use in the manufacture of optical glass. For this purpose, pots based on Bleininger's formula have been made and used with great success, one firm in particular saying that they had been able to overcome all their initial difficulties with pots, and had obtained an article which was completely free from corrosion even in the presence of heavy barium glasses.

The usual information, however, as a result of inquiry at many glass works, was that the pots at the present time were very bad, and that there had been no good pots since the supply of German clay had failed. Some manufacturers seemed to regard German clay as an absolute necessity for making good glassware. The truth is, of course, that in America there must be many excellent clay deposits, which have, however, not yet been fully exploited and brought to the notice of clay manufacturers.

The usual practice followed by pot-furnace works appears to be to buy pots from a firm making refractories. Frequently, such purchased pots have to be transported long distances. For example, pots used in works in the neighbourhood of New York had come all the way from Muncie in Indiana, a distance not far short of 800 miles. At one large works, where glass refractories were made in great numbers, namely, the Buckeye Clay Pot Co., Toledo, the view was taken that probably the British practice was much better, namely, that the clay was sent to the glass works and there built up into pots either by a permanent or a visiting pot-maker.

The drying of pots is certainly receiving some study. For example, at one or two works hygrometers to register the state of moisture in the pot room were observed in use, and at one of them perforated steam pipes ran across the ceiling, so that steam could be injected into the air when the degree of humidity fell below a certain value.

It may also be mentioned that the Philadelphia Textile Machinery Company has erected a special plant on trial in one or two glass works for the purpose of drying pots expeditiously. The outcome of these trials will, it is hoped, be communicated to the Society at a later date. Dr. Travers reported to the writer that at one research institution this system is in satisfactory operation for the drying of quite complicated clay forms.

XIII. General Labour Conditions.

Unfortunately, the writer was unable, as he fully hoped, to make the acquaintance of some of the leaders of Trade Unions to discuss the position of labour and to obtain the men's point of view. The only information gained, therefore, was that derived from individual factories as supplied by the management, and it appeared that there were distinct differences in working conditions in different parts of the country, more especially in pot-furnace works. Piece-work naturally obtained in bottle factories everywhere, and the 8-hour shift was generally adopted both in machine- and hand-operated factories, although the writer was informed of one factory in which semi-automatic machines were worked by four 6-hour shifts. Piece-work was not general in pot-furnace works. Indeed, in some places there was still limitation of output.

In the bottle trade the writer was informed that the skilled hand operators earned from $8 to $10 per day, whilst the unskilled members of the shop of seven workers might get $2½ per day. The unskilled labour in many places was coloured (boys or girls). At the present time coloured people are not permitted to join Trade Unions, and therefore have no opportunity of becoming skilled workers. At one factory employing partly non-Union labour, the management said that it was quite prepared to give the coloured labour a trial, and saw no reason why it should not perform just as satisfactorily as the white along certain lines.

Although the rate of $8 to $10 obtained in one district, the wages of a successful skilled bottle blower might even exceed $100 per week, as was mentioned to the writer in one or two works.

In pot-furnace works there is considerable shortage of skilled men. Blowers may earn as much as from $10 to $12 per day, and sometimes $16. The bulb shaper may get $8, whilst boys, usually difficult to coax into this branch of the industry, were stated at one place to be receiving as much as $6 per day, although at another works they were receiving but $16 per week, a much more usual rate of pay. The rates of pay for skilled operators at another works, making artistic ware, were stated to be $1.35 per hour for the maker and $1.27 for the servitor.

In pot-furnace works, the shift is usually split into two turns, each of about four and a-half hours. In quite a number of works a definite number of articles per turn appears to have been set, and when this number was reached the workers ceased operation and went home.

At one works in New Jersey the position was, in the opinion of the management, quite unsatisfactory. The operator was paid a definite daily wage, this being given to him whether he reached the fixed number or not, the supposition being that the worker would do his best to obtain the required output. Naturally, with workmen of different temperaments to deal with, the arrangement did not always lead to satisfaction on the part of the employer.

One other special arrangement reported in operation at a works in Baltimore deserves notice and commendation. The arrangement was that in the summer the piece-rate was fixed at a conference between the workmen's representatives and the employers. If, however, for any cause a disagreement arose during the working year in regard to the price to be paid for making a specific type of article, the workmen did not strike, but continued working, and the matter in dispute was left over until the succeeding summer meeting. If the men's contention turned out on conference to be accepted, then they were paid retrospectively. Obviously, this method was bound to make for continuous and more harmonious working.

Lastly, in regard to working conditions, attention may be directed to the fact that American factories in the glass industry are in operation for a longer working period during the week than our own. In hand-operated factories making glass bottles, work continues until about 2 o'clock on Saturday afternoon during the months from May until October. In the winter months the work proceeds all day until 6 o'clock. Where completely automatic installations are in operation, as, for instance, at the factories operated by Owen's machines, the latter continue production until the early hours of Sunday morning. Moreover, in these factories no summer break occurs, since there are no glass operators who are inconvenienced by the heat during the hot summer spell. It is the practice in such works to continue operation until it is essential for a furnace to be turned off for repairs. It may be mentioned that in the Libbey-Owens window-glass plant the operation of the machines continues every day in the week, Sundays included, for as long as the furnace lasts.

XIV. Science and the Glass Industry in America.

It may be a surprise to readers to learn that the glass manufacturers of America are considered to be just as much rule-of-thumb men as in this country. True it is that the main triumph of the American glass industry up to the present time consists in its wonderful application of engineering processes to large-scale production, not only for bottles, but also for that class of goods which is intermediate between the bottle trade and the higher types of glass, such as the artistic, of necessity made by hand. Whilst, therefore, the engineer has had very large scope for some years past, chemists and physicists have only begun to come into their own during the War. It appears that there were very few glass works in America prior to the War which employed a staff of chemists, or even a single chemist. As the results of their efforts during the War, however, the highly trained scientific men who went out from the Geophysical Laboratory and the Bureau of Standards as a matter of duty to serve during the War have been induced in many cases to stay in the industry. Indeed, only an odd man or two have returned to Washington, and some of these are returning there in order to run the laboratory which has been specially set up, equipped with large furnaces, for the scientific study of glass.

Although there is as yet no movement amongst the glass manufacturers to form a large research association, such as we now have the good fortune to possess, individual manufacturers are engaging chemists and physicists at a greater rate than in our own country; and it behoves our own manufacturers to think well ahead and to endeavour to realise that, as glassmaking is essentially a process in which chemical and physical changes are fundamentally concerned, it is only common sense for some person who understands them to be in charge of them.

In the course of the writer's journey he had the pleasure of meeting more than sixty chemists and physicists engaged in the glass or the glass refractories industry in America. It certainly would be difficult to find more than half this number in all the corresponding factories in the United Kingdom. Not only are immediate works problems being given attention, but also such subjects as the viscosity of glass, and other apparently abstract problems have been recognised as of first-rate practical importance in two or three factories where such researches were found to be in progress.

XV. Miscellaneous.

In a report of this character it is only possible to deal with some of the more salient features of the American industry so far as they are of wide interest, and quite a number of detailed subjects have not hitherto been mentioned. Nor, indeed, is it possible to make mention even of some subjects.

The production of illuminating ware is carried out on a large scale; so also is tableware, including both lead and high quality lime glass (semi-crystal), whether fully hand-cut or worked up from figured blanks. In regard to the latter, many of the types, in the writer's view, lacked artistic design, the patterns being far too elaborate. On the other hand, some beautiful dishes and other articles were seen, and the secret of success, outside the subject of design, lies in the care taken in the preparation and maintenance of the moulds and in finishing the glass surface.

Coloured glass is much less employed in artistic glass than in Britain, but three factories have developed the colouring of glass to a high pitch. It is probably a matter of personal taste only, but in the writer's view, only one factory in America can vie with the best coloured artistic glass produced in this country in regard to general beauty of conception and effect.

In regard to illuminating ware, many types, shades, globes and reflectors and objects which are to be specially decorated, are hand-blown, as far as possible two at a time, but some types of reflector, including the so-called moonstone or alba ware, are made on a large hand-operated press. The cheaper gas and electric globes are made, however, in large quantities by semi-automatic press machines, such as those of the Edward Miller, the W. J. Miller and O'Neill Glass Machinery Companies, the machines being very similar to those for making wide-mouth bottles. The appearance of the globes can be, and is in many cases, improved by sand blasting the surface either wholly or partly, or by use of a composition which is sprayed on.

For light blown articles, machinery is not very much employed, but paste mould machines for the purpose of making lamp chimneys simultaneously with a light blown tumbler are sold both by the Edward Miller and the W. J. Miller companies. Where tumblers and special types of illuminating ware are blown by hand, as is very largely the case, the system in general use is to have quite a large "shop" (or "chair"), either of seven or eight workers, and so to divide the work that the skilled operators do nothing but skilled work, the other operations being carried out by much cheaper, unskilled labour.

In regard to window and plate glass, the writer only had the opportunity of visiting five factories, quite an insignificant proportion of the large number in operation in the States. Of the window glass factories, one was hand-operated, two were factories in which the cylinder was drawn by different types of machine, whilst the fourth was the Libbey-Owens Window Glass Company at Charleston. During the course of his journey, several persons told the writer that the Libbey-Owens process was still surrounded with difficulties detrimental to commercial production. It is a special pleasure, therefore, for him to be able to state that at the time of the visit many of these difficulties had been overcome, and sheet glass with a perfectly plane surface was being produced with a smoothness of working on the part of the furnace and the machine that was fascinating to watch.

In the works in question there are six tank furnaces all in operation under one roof. The glass flows from the working end of the furnace into a shallow trough, and from there is raised continuously in the form of a sheet which passes over a metal roller of special composition and down a horizontal lehr of about 200 ft. in length. The continuous belt which carries the sheet is extended outside the lehr where an operator trims off the edges and passes the cut sheets forward into the cutting shops. The works itself is a model organisation, and is noteworthy for the fewness of the men employed, whilst the degree of success already attained in a process which is epoch-making in the sheet-glass industry is a great tribute to the capability of the management.

The management of some of the glass factories presented a number of interesting features. One of them was the attempt to enlist the workers' interest in the volume and quality of the output. It was found to be quite a feature of some of the well-organised works to have a record set up in a prominent place in the factory, stating the output on each particular day of the week, and the losses due to breakage under their respective headings. Great attention is also paid to the reduction in the losses due to breakage. At one electric lamp factory, a record was placed in a position confronting each girl operator, stating the breakage on the previous day. The writer was told that the operators had accepted the method in a very sporting spirit, and there was a keen sense of competition to reduce the loss due to breakage; indeed, the method had been singularly successful. In some bottle factories, too, prominent notices were placed in the works, pointing out that the credit of the firm was wholly in the hands of the employees, who could either extend or mar that reputation. For example, the attention of packers was drawn to the fact that it was much more expensive to place a bad bottle in a customer's consignment than to throw it on to the cullet heap. At another works, employing Owen's machines entirely, a large printed statement was posted up by each machine, stating in detail the many and varied defects of bottles which might from time to time be observed, and the probable cause of those defects, with directions to the operator for remedying them. All these methods are well worthy of consideration by manufacturers, since it is a mistaken idea to believe that workpeople and employees in general are not interested in their work. The only way to success is to assume and to stimulate their interest.

The writer's last words must be once more of thanks to those many friends who made the journey both for himself, Mr. Connolly and Dr. Travers so exceedingly pleasant and who, by their frankness in discussing subjects of mutual interest and their courtesy in so readily granting permission to visit works, indicated their high conception of the meaning of scientific co-operation. The English members of the Society who join the party to visit the States in the summer of 1920 will learn more fully than the writer can express what American hospitality really is.

Department of Glass Technology,
The University, Sheffield.

Appendix.

The writer was approached by one of the members of the Society for a copy of the appended table. The member in question thought that it was so useful as to warrant its reproduction, and suggested that this should be done.

The table in question has already been published; indeed, it was merely extracted from the catalogue of the Chowning Regulator Corporation, whose device has previously been referred to (p. 174). It may at any rate be of service in emphasising the very great desirability that all firms should keep systematic records.

The table attempts to correlate the output of glass with the consumption of fuel when the regulator was put into commission. It is as follows:—

Gas Pressure Regulator Test. Thatcher Manufacturing Company, Elmira, N.Y.

No. 2 Tank Furnace Used.

Date—1915.	Tons glass melted.	Tons coal used producers.	Tons coal used prod. steam.	Average tons coal per day in producer.	Average tons glass melted a day.	Lb. coal used per ton glass melted.	Cost prod. coal a day at $3 a ton.	Cost prod-steam coal a day.	Average steam pressure blower nozzles.	Lb. steam used per hour.	Cost steam coal a day at $3 a ton.	Lb. water per lb. coal.	Average temperature tank.
March 30 to April 5	153·9	91·12	7·00	13·00	21·90	1183	$39·00	$42·00	16·3	625·0	$3·00	0·57	1269
April 6–12 ……..	181·6	96·55	7·42	13·70	25·94	1008	41·00	44·28	18·1	663·0	3·18	0·58	1294
April 13–19 ……	168·4	93·40	7·01	13·34	24·00	1107	40·02	43·17	16·5	629·0	3·15	0·56	1290
April 20–26 ……	119·7	88·39	5·83	12·62	17·10	1476	37·86	40·36	10·9	518·0	2·50	0·45	1269
Average ……	155·9	92·36	6·81	13·16	22·2	1193	39·47	42·45	15·4	608·9	2·95	0·54	1280
Test without Regulator.													
May 10–17 ……..	138·9	97·09	7·52	13·87	19·85	1382	$41·61	$44·83	18·7	675·0	$3·22	0·582	1295
	150·7	98·71	7·65	14·10	21·50	1310	42·30	45·58	19·2	684·0	3·28	0·584	1311
	121·9	91·87	7·58	13·12	17·41	1507	39·36	42·61	18·0	660·0	3·25	0·620	1253
	143·67	92·85	7·07	13·26	20·50	1293	39·78	42·81	16·7	634·0	3·03	0·500	1270
Average ……	138·79	95·13	7·45	13·58	19·81	1373	$40·76	$43·95	18·1	663·0	$3·19	0·571	1282

Summary.

Saving based on same Melting Rate-Producer Coal	5·5 per cent.
Saving based on same Melting Rate-Producer Steam	11·3 per cent.
Saving per year	$875·00

XIX.—*The Reversible Expansion of Refractory Materials.*

By H. J. HODSMAN, M.Sc., F.I.C., and PROF. J. W. COBB, C.B.E., B.Sc., F.I.C.

(*Read at the Sheffield meeting, November 19th,* 1919.)

Introduction.

THE change of volume which occurs on heating is one of the most important physical properties of refractory products and may at times be decisive in the attainment of success in applications to large-scale practice. The net change may be due to two factors, the one permanent and usually spoken of as the "after-contraction" or "after-expansion," the other temporary, solely dependent on temperature and therefore reversible. Hitherto, the latter has not received the attention which it deserves. In neither the specification of the Institution of Gas Engineers nor that of the Society of Glass Technology has it been possible even to hint at any standards. This is the result of the want of data and experience on the point, due possibly to the lack of convenient methods of measurement. It was to obtain more precise data on thermal expansion and contraction that the apparatus to be described was constructed and put into use in 1914, but owing to the exigencies of the war, the work had to be put on one side and could only be resumed in 1918. The method was adopted largely because it facilitated the detection of changes in the rate of expansion as the temperature was raised.

The methods so far employed by investigators of expansion coefficients are of two kinds, one absolute and generally of a character too elaborate to come readily into general use, and the other relative, involving measurements of expansion as compared with that of a standard material. Several methods of measuring expansion absolutely at high temperatures have been described by Le Chatelier [*] and his collaborators, Coupeau and Damour, Holborn and Wien,[†] and Coppée. Some results obtained with firebrick by the Coppée method have been reported by Mellor. A brick to which two platinum points are fixed is heated up in a furnace. The resulting movement of these points can be followed by two telescopes mounted on a bar outside the furnace, and the extent of the movement thus measured.

---

[*] *Bull. Soc. d'Encouragement*, October, 1898, 1274.

[†] *Trans. Eng. Cer. Soc.*, 1916–17, **16**, Pt. 2, 270.

Expansions relative to porcelain were measured by Le Chatelier up to 1000° by an optical method.* Holborn † made measurements relative to fused silica, but apparently at comparatively low temperatures only. Boeck ‡ has used apparatus resembling the one described below.

Before proceeding to any detailed consideration of the method and results of our investigation, the magnitude of the changes in volume on heating large-scale structures may be roughly calculated and noted. The specifications of the Institution of Gas Engineers require a grade 1 silica brick material, when heated to Seger cone 12 for two hours, to show no permanent change of length (expansion) greater than 0·75 per cent. In the experiments to be described it was found that the mean coefficient of expansion of such a material previously fired to cone 9 was 695×10^{-8} from 15° to 1000°. The temporary expansion from 15° to 1350° (cone 12) may be taken for purposes of illustration as 0·695 per cent., assuming no further expansion above 1000°. These two expansions are superposed, so that the total expansion with a silica brick complying with specification, may be 1·44 per cent., or nearly 1½ feet per 100 feet of wall. Where large structures are heated, as in coke-ovens, the necessary allowance for expansion becomes of great importance, and has to be considered carefully in design, erection, and working. An expansion allowance of 3/16 inch per foot for silica material, that is, 1·56 per cent., is sometimes made a working rule.

With fireclay materials the case differs. Grade I products, to satisfy the specification of the Institution of Gas Engineers, must not show a permanent linear change greater than 1 per cent. on heating for two hours to 1410° (cone 14), but with clay products this is in general a contraction, and therefore opposite in sense to the reversible thermal expansion. The mean coefficient of expansion found for a fireclay (Farnley) brick of grade I quality from 15° to 1000° was 509×10^{-8}, or a total reversible expansion of about 0·5 per cent. up to 1000°. The net change of linear dimensions of such a product on the limit of grade I, when heated to 1000—1400°, may, therefore, be a contraction of about 0·5 per cent., or 6 inches per 100 feet. It can easily be imagined that a true analysis of these changes in dimension is worthy of considerable attention where it becomes necessary to minimise leakage of gas or liquid, as in retorting, recuperation, and many furnace operations.

Even in apparatus on a relatively small scale, where the absolute magnitude of dimension changes is small, these may still be of vital importance. Some articles must perforce be subjected to drastic temperature influences. Thus a fresh glass pot is transferred red hot from the pot arch to the glass furnace through cold air, and is subjected to the chilling action of the material charged into it. Considerable strains must result, greater in amount as the local shrinkage of the material of the pot is greater, and tending to cause cracking. The degree of disintegration will evidently depend also on the cohesive strength and plasticity of the portions affected at the temperature existing, but this is a matter requiring separate investigation. A minimum and uniform coefficient of expansion over the range of the temperature change is, however, plainly desirable, and this may well be a decisive factor in the selection of materials for glass-pot manufacture. There is a critical temperature a little below 600°, when many pot-clays in cooling show a sudden contraction, below which it would apparently be very dangerous to allow the pot to cool even locally without risk of fracture. In the firing of clayware, especially large articles, a knowledge of the ranges where rapid changes of temperature are dangerous and where permissible is equally desirable, and useful information can, we believe, be obtained from a study of such heating and cooling curves as are given later. Crucibles used for metal melting must withstand sudden and large changes of temperature, and the same applies to gas-retorts and coke-ovens which are charged with cold material. Large coefficients of expansion and more particularly sharp discontinuities in the expansion curves are therefore undesirable.

---

* *Bull. Soc. d'Encouragement*, Feb., 1895.

† *Zeitsch. Elektrochem.*, 1912, **18**, 823.

‡ *Trans. Amer. Cer. Soc.*, 1912, **14**, 470.

Commercial fireclays and silica products are particularly prone to abnormalities of expansion, and special attention has been given to the dissection of these.

Description of Apparatus.

The furnace consisted of an electrically heated fireclay tube, 18 inches long, closed at one end by a fireclay plate. It was wound with nichrome wire to convey the heating current and the pitch of the winding was reduced at both ends, so as to compensate for the greater rate of cooling there, and thus ensure a long zone of approximately constant temperature in the tube. The winding was plastered over with fireclay paste, and the whole placed axially, as in Fig. 1, in a shell of tin plate filled with light magnesia. The current was regulated by resistances in series and in parallel, 7 amperes at 200 volts being required to maintain 1000° over a considerable range of the furnace. The furnace placed horizontally contained the expansion apparatus proper. This consisted of a tube of fused silica, 3·8 cm. in diameter, 50 cm.

in length, with the open end projecting from the furnace and having attached a brass tube, *E*. The specimen under test *B* (usually about 20 cm. long and 2·5 cm. thick) was placed inside this silica tube, together with distance pieces of silica *C* and *D* of such a length as to bring it into the zone of uniform temperature. To the distance-piece, *D*, was cemented another brass tube, *F*, which could slide between guiding screws within the outer brass tube, *E*, and permitted a circulation of air between the two. Both the inner and the outer brass tubes carried attached pieces of glass plate placed in juxtaposition, each bearing a fine scratch. Any relative movement of the scratches could be observed and measured. Relative displacement would be due to the difference of expansion of the specimen and of the length of fused silica tube encircling it. The fused silica distance pieces and the portion of the outer silica tube encircling them would be expected to undergo the same expansion, and so not affect the readings. The distance between the marks on the two glasses was measured at different temperatures by means of a microscope fitted with a micrometer eyepiece. One division of the scale of the micrometer eyepiece corresponded with 1114×10^{-6} mm. Temperatures were observed by means of a platinum–platinum/rhodium thermocouple attached to the outer silica glass tube, the junction being about the middle of the specimen *C*. The expansions were, of course, measured relatively to silica glass, which has a low and comparatively constant coefficient of expansion, as shown by the following values obtained by Kaye,* which we used in obtaining the absolute expansions of our specimens: 0—30°, 42×10^{-8}; 30—100°, 53×10^{-8}; 100—500°, 58×10^{-8}; 500—900°, 50×10^{-8}; 900—1000°, 80×10^{-8}. Above 1000° abnormalities revealed themselves, which is confirmed by our observations, so that it does not appear possible to extend the method in its present form to temperatures above 1000°.

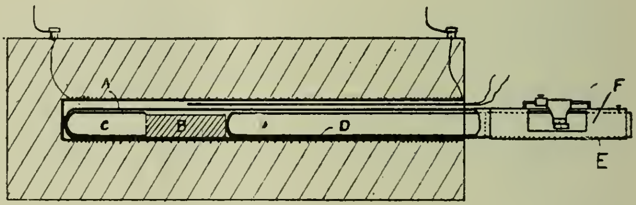


FIG. 1.

---

* G. W. C. Kaye: "Expansion and Thermal Hysteresis of Fused Silica" (*Phil. Mag.*, 1910, [vi], **20**, 718).

Tests of Apparatus.

(a) *Temperature distribution within the furnace.*

The specimen occupied a zone of the furnace 20 cm. long. A test at 1000° showed that 10 cm. were constant to 5°, 15 cm. to 15°, and that the extreme variation of the whole 20 cm. was 30°. The extreme difference from the average temperature was 15°. The correctness of the temperature measurements is supported by the result obtained for the inversion of silica (α-quartz to β-quartz).

(b) *Comparison between the temperature recorded and the actual temperature of the specimen.*

The temperature was normally raised at the comparatively slow rate of about 130° per hour, so as to ensure uniformity in the heating of the specimen, and thus to bring out those critical temperatures where sudden changes in the rate of expansion occur. It was thought that the temperature indicated by the couple might differ appreciably from the actual temperature of the specimen. Consequently, an additional couple was embedded in a specimen, *C* (fireclay), and a heating and a cooling run taken, the temperatures of the two couples being observed simultaneously by reversals by means of a Pohl's commutator. In the heating experiment the results showed that the specimen was about 10° cooler than the thermojunction up to 200°, above which the temperatures were practically identical. The average difference recorded up to 1000° was only 1·5°. In a cooling test from 1000° the specimen was on the average 14° hotter than the thermocouple outside, with an extreme difference of 22°. While this difference is objectionable, it was not practicable to introduce a couple so as to touch the specimen, and alteration of dimensions to permit this would be undesirable as facilitating convection currents between the inner and outer tube. The temperature difference is, however, small, and certainly not responsible for the peculiarities observed in the cooling curves obtained from such materials as clays, silica, and siliceous clays. This is clearly indicated by the coincidence of the heating and cooling curves not infrequently observed.

(c) *Blank experiment carried out, using a silica glass tube as the sample under test.*

The results were satisfactory. There was very little relative movement between the marks on the two glasses, a negligible decrease in length being indicated at the higher temperatures.

Tests made and results obtained.

Samples of typical materials were obtained, shaped as necessary into the form required, and tested by the method described, with results which are detailed below. The results of chemical analyses and the coefficients of expansion are collected in tables I and II. Unless otherwise stated, the test pieces were burned to cone 9, taking seventy-two hours. The specimens were square prisms about 20 cm. long and about 1·7 cm. edge. Their expansions are shown in Figs. 1 to 6 plotted against temperature. One division in a horizontal direction equals 0·1114 mm.

Kaolin.

This material was chosen as representing pure clay, essentially silicate of alumina, $Al_2O_3,2SiO_2,2H_2O$, with the minimum of foreign admixture. The kaolin was sieved through a standard 16-mesh (I.M.M.) sieve, made stiff-plastic with water, moulded, dried, and burned to cone 06 in forty-eight hours or cone 9 in seventy-two hours, the approximately corresponding temperatures being 980° and 1280°. The permanent contraction on burning to cone 06 from the air-dry condition was 1·5 per cent., and to cone 9, 9·3 per cent. The material (Fig. 2) is seen to possess a small coefficient of expansion up to 100°, then a much larger coefficient to 200°, and (what is very important) from 200° to 1000°, a remarkably steady coefficient, the cooling curve (not shown) lagging a little behind the heating curve. The actual expansion is rather less than that for alumina.

Alumina.

Fine calcined alumina as prepared commercially from bauxite for the manufacture of aluminium was made up with the addition of ball clay (10 per cent.) to allow of binding, mixed with water to a well-damped state, and rammed into the mould. The contraction on burning to cone 9 was 1 per cent. It was found (Fig. 2) to have a nearly steady coefficient of expansion, increasing slightly with temperature. A small, permanent contraction was observed in the first heating, which may have been due to the friability of the test piece. This view was supported by the observation that the second and third curves were very nearly coincident, and showed somewhat greater expansion than was obtained on the first heating of the pencil. The expansion of fused alumina was also studied, using as a test piece an "Alundum" tube. It showed a uniform coefficient of expansion rather less than that of the calcined alumina (Fig. 6). It may be noted at once that the wide variation displayed by different forms of silica (see below) are entirely absent in the case of alumina.

Silica.

A ground quartzite ganister containing 96 per cent. of SiO_2 was taken for a first study of silica. It was sieved through a 25 mesh (I.M.M. Standard) sieve, mixed with 3 per cent. burned plaster added as a slip, moulded, dried fairly hard, and slowly heated to cone 9 over seventy-two hours. A noticeable feature (Fig. 2) was the very large expansion taking place from 550° to 590°, the curve becoming almost parallel to the horizontal axis, and so denoting a large and sudden expansion. This, no doubt, corresponds with the inversion of α-*quartz* into β-*quartz* known to occur at 575°. From 590° to 1000° there was no further increase in length; a very small negative coefficient suggested by the curve obtained was probably that observed in the blank test using fused silica as the test-piece. The second heating curve showed a slightly decreased expansion, a further diminution being seen on the third heating. The cooling curve is very peculiar, for after running from 1000° to 600° very close to the heating curve, a marked contraction took place during the next 100°, so that in that region of temperature the contraction on cooling was even greater than the expansion on heating. A

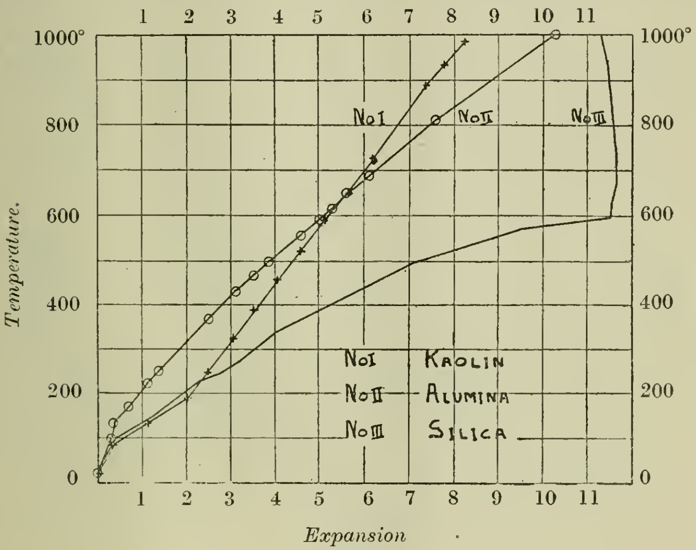


FIG. 2.

permanent expansion of 0·12 per cent. was found after the first heating.

No inversion to *tridymite* up to 1000° could be detected in the experiment by any volume changes above 800°. Other forms of silica require examination, as do some peculiarites in the behaviour of quartz, but what stands out clearly in the results obtained is the large and sudden expansion and contraction between 500° and 600° —just above visible redness, followed by an almost complete constancy of dimensions between 600° and 1000°. It indicates clearly the care which must be exercised in the treatment of a quartzitic silica structure of any kind just about dull redness, if the stresses consequent on volume changes are to be avoided, and also the comparative immunity from damage of this kind which is secured when the silica work is at a good red heat.

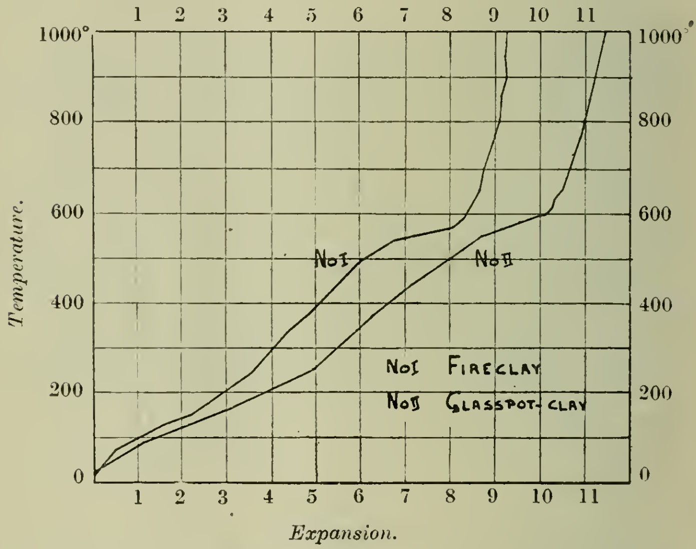


FIG. 3.

Fireclay.

This was a more composite material than the previously mentioned samples, but perhaps the most important in practice. A fireclay from Farnley (Leeds district) was tested first. The test pieces were burned in a works kiln to cone 06 and others to cone 9, with contraction of 1·0 per cent. from the air-dried condition. The results (Fig. 3) obtained bore striking evidence of the great influence exercised on the expansion by free silica present in the clay. There was the same marked expansion between 500° and 600° as noted with silica, and from 600° to 1000°, although expansion did occur, it was very much smaller than with kaolin. The expansion lay between that of silica and of kaolin, but closer to that of silica than would have been expected from a first consideration of the probable influence of chemical composition. Heating and cooling curves with this material, as with silica, did not coincide. The area enclosed between a heating and a cooling curve (after the first heating and cooling) was within experimental error constant, so that the changes are cyclic. The first differed from succeeding cooling curves. Subsequent heatings showed a slight increase in the coefficient of expansion, that is, just the opposite to the behaviour of silica. A permanent contraction of 0·10 per cent. accompanied the first heating. It is plain that the remarks made above on the care necessary in the treatment of silica goods will apply equally to this and similar fireclays.

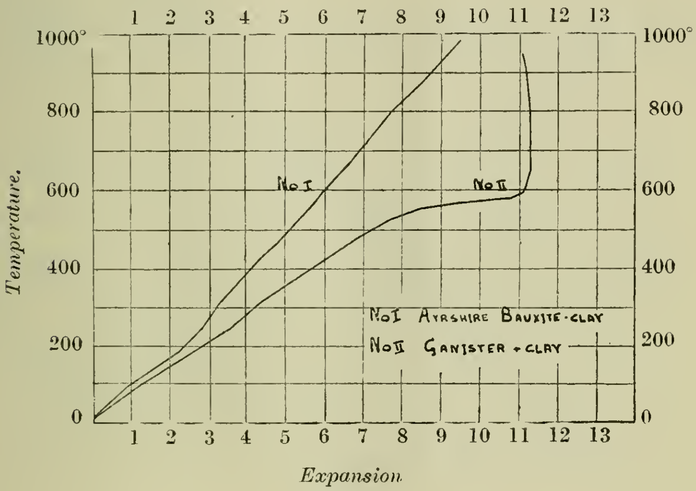


Fig. 4.

Clay–silica mixture.

Test pieces were next made up from a mixture in equal parts by weight of the silica and Farnley fireclay previously tested. They would represent in composition the so-called siliceous firebricks containing about 80 per cent. silica, now widely used in coke-ovens, retort settings, and furnaces generally. Expansion and contraction (Fig. 4) were almost exactly the same as those obtained from silica alone, and not intermediate between kaolin and silica. It is suggested that the clay pressed between the grains of silica during moulding had contracted on drying and burning, the pores left being then sufficient to allow of the subsequent expansion of the clay on heating without exerting any expansive thrust. What expansion did occur would then be due to the thrust of opposed silica grains.

A Scottish Fireclay (Glasgow district), richer in alumina than the Farnley fireclay, showed the same sudden expansion between 500° and 1000°, due, presumably, to free silica, but in a much less marked degree, and the same may be said of a typical glass pot mixture (Fig. 3), of which the basis was fireclay from the Halifax district.

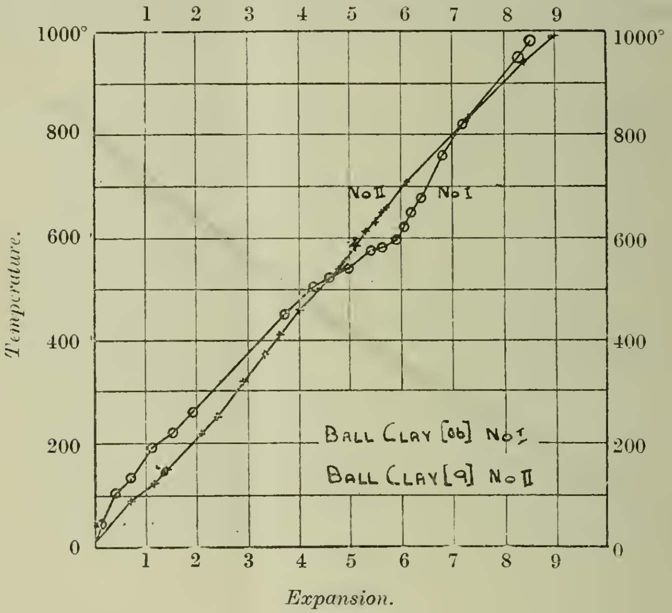


FIG. 5.

Ball-clay.

An interesting observation was made on the behaviour of test-pieces prepared from a tough and plastic fine-grained Dorsetshire ball-clay. A test-piece which had been previously burned to cone 06 showed (Fig. 5) a flattening of the curve between 500° and 600° which was quite distinct, although less pronounced, than with any typical fireclay. This test-piece was hard, but porous and unvitrified. On repeating with a test-piece previously burned to cone 9, the flattening had vanished completely and a straight line curve was obtained almost exactly the same as had previously been obtained from kaolin. This test piece was close grained, non-porous, and semi-vitrified. This result was very suggestive. It indicated presumably that the action between the fine-grained free silica (quartz) and the clay mass which had occurred during the burning from cone 06 to cone 9, whether it result in solution, combination, or transformation, was sufficient to suppress the influence of the silica. Compared, too, with other results obtained, it confirms the view that quartz is the form of silica normally present in our clays.

Bauxitic clay (*Ayrshire*).

A highly aluminous clay containing more than 40 per cent. of alumina from Ayrshire, and supplied by Mr. G. V. Wilson, of the Scottish Geological Survey, was tested. The ground clay was mixed with a little water, moulded into shape, dried, and burned to cone 9.

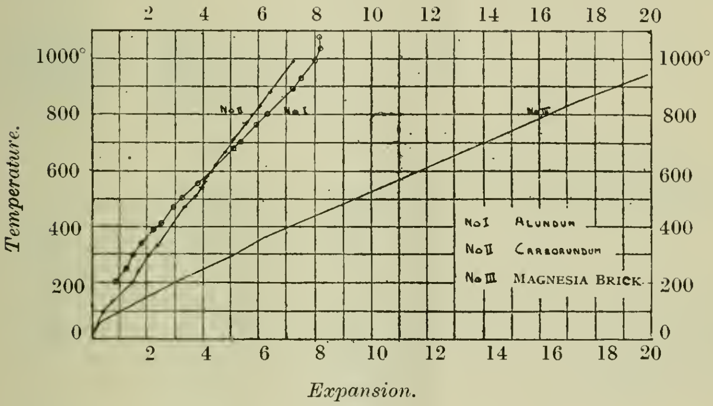


Fig. 6.

The heating curve obtained (Fig. 4) was simple and continuous, and except for a small inflexion about 200° almost a straight line up to 1000°. In this respect it resembles both kaolin and alumina, which have also simple coefficients, while its expansion curve lies in an intermediate position. The suppression of any discontinuity between 500° and 600° points to the absence of free silica (quartz).*

---

* According to Mr. Wilson, the silica is probably all combined with alumina as *kaolinite*, and the remainder of the alumina present as a mineral with the composition Al_2O_3,H_2O.

Magnesia brick.

This test piece was prepared from briquettes ready for pressing into commercial magnesia bricks. It contained nearly 10 per cent. of oxide of iron, and was brown and hard. It showed an approximately straight line expansion curve up to 1000°. This material had the highest coefficient of expansion of any tested over the range 15° to 1000°, although up to 600° the average expansion of silica was nearly the same (Fig. 6).

Carborundum.

This was the commercial material bonded with a little clay. Its expansion was continuous, and very nearly the same as that of kaolin (Fig. 6).

TABLE I.

	From.	Mean coefficient of expansion. Cone 9 specimens.	Percentage expansion from 0° to 1000°
Alumina* (+ 10 per cent. ball-clay)................	15—1000°	624×10^{-8}	0·62
Second and third heating.			
Silica (quartzose)	15—500°	894×10^{-8}	—
First heating †.	500—600°	2445×10^{-8}	—
	600—1000°	-15×10^{-8}	—
	15—1000°	683×10^{-8}	0·68
Kaolin	15—1000°	531×10^{-8}	0·53
Ball-clay	15—1000°	575×10^{-8}	0·57
Magnesia brick	15—1000°	1274×10^{-8}	1·27
Farnley fireclay	15—500°	769×10^{-8}	—
First heating.	500—600°	1275×10^{-8}	—
	600—1000°	183×10^{-8}	—
	15—1000°	583×10^{-8}	0·58
Scotch fireclay	15—500°	745×10^{-8}	—
	500—600°	1220×10^{-8}	—
	600—1000°	294×10^{-8}	—
	15—1000°	611×10^{-8}	0·61
Carborundum....................	15—1000°	471×10^{-8}	0·47
Clay + ganister (cone 10) ...	15—500°	883×10^{-8}	—
	500—600°	2278×10^{-8}	—
	600—1000°	-29×10^{-8}	—
	15—1000°	655×10^{-8}	0·65

* Assuming the influence of the ball-clay to be additive, the calculated coefficient for pure Al_2O_3 becomes 680×10^{-8}. The correction so made is seen to be small.

† The expansions on successive heatings were slightly different (see text).

TABLE II.

Analysis of the Materials Tested.

	Raw kaolin.	Raw ball-clay.	Raw fire-clay (Farnley).	Calcined alumina +10 per cent. ball-clay.	Magnesia brick.	Silica.	Raw Scottish fire-clay.	Ayrshire bauxitic clay.	Glass-pot clay.
Hygroscopic moisture ...	0·14	1·24	—	—	—	—	0·12	0·75	—
Loss on ignition	12·78	11·36	9·36	—	—	—	12·78	13·96	—
Silica (SiO_2) ...	46·20	51·62	63·48	5·4	5·80	96·04	51·14	36·65	63·0
Alumina (Al_2O_3)	38·49	32·09	22·39	94·2	1·75	1·42	31·89	43·83	—
Titanium dioxide (TiO_2)	Nil	—	1·10	—	—	0·05	0·87	3·20	—
Ferric oxide (Fe_2O_3)	0·58	1·23	1·33	0·13	9·71	0·27	2·46	0·67	—
Lime (CaO) ...	0·30	0·75	0·70	0·01	2·15	2·0	0·40	0·49	—
Magnesia (MgO)	0·19	0·69	0·52	0·01	79·92	tr.	0·33	0·00	—
Soda (Na_2O)...	0·81	1·55	0·88	0·01	—	—	0·22		
Potash (K_2O)	0·65	0·59	0·47	0·01	—	—			

Summary.

The results disclose great differences in the behaviour of different refractories when heated up to 1000°. A number of these, including calcined alumina, magnesia brick, carborundum, calcined kaolin, and hard calcined ball-clay expand regularly over the whole range. These results do not, therefore, suggest the existence of any molecular changes. The behaviour of silica (quartz) is in marked contrast, in that the inversion of α to β *quartz*, accompanied by a very large expansion between 500° and 600°, is succeeded by a range from 600° to 1000° through which the dimensions are practically invariant. Specimens of burnt fireclay containing free silica reveal the same change, but in a somewhat less marked degree. Some clays resemble more nearly kaolin itself, while others approach in this respect the behaviour of silica. A mixture of half fireclay and half silica containing approximately 80 per cent. of silica behaves like silica. Specimens cut from glass pot fireclay mixtures were examined and were not found materially different from the fireclays. It is evident that pots made from kaolin ball-clay mixtures or from clays containing no free silica (quartz) will be quite different in their behaviour on heating and cooling from pots of which the basis is fireclay, and also that great care will be necessary in the treatment of pots of the latter description in the range 500° to 600°. A remarkable feature of the results, not easily accounted for, is the contraction just below 600° on cooling clay and silica which actually exceeds the corresponding expansion on heating. With silica and fireclays this is especially marked, and suggests that a rapid cooling of ware or glass pots through the region 600—500° must be fraught with quite special risk of cracking. The behaviour of raw clays and of silica in forms other than quartz is under examination. Most refractories examined expanded roughly $\frac{1}{2}$ per cent. up to 1000°, but magnesia brick more than twice this amount.

Finally, we should like to acknowledge the valuable help in experimental work rendered by Mr. H. S. Houldsworth, of this University, and by Mr. C. A. King, of the Farnley Iron Co., and to tender our thanks to Mr. G. V. Wilson (of the Scottish Geological Survey), and to Messrs. Wood Bros. Glass Co., Ltd., Messrs. Corbett and Co., Ltd., and Messrs. Duroglass, Ltd., for the provision of samples.

THE UNIVERSITY,
LEEDS.

DISCUSSION.

MR. S. N. JENKINSON: This paper by Prof. Cobb and Mr. Hodsman is not only of great interest to glass manufacturers, but is also of great importance, and although the authors do not record any work above 1000°, I hope that they will continue their investigations to higher temperatures. Before the results of such work are applied, it is most desirable that we should reconsider our present methods for the heat treatments of our pots. The heating up of a pot arch has become standardised in each works, and, in the majority of cases, excellent results are obtained, but if pots of a totally different composition are used, and the standard course of arching followed, bad results will almost certainly be obtained. In such case, the glass manufacturer would probably say that the pots were bad, and there the matter would end. Actually, the pots might be extremely good, the fault being that the arch treatment was not suited to the particular clay composing the pot. It is not every glass manufacturer who has a pot arch in which the temperature can be controlled at will by the regulation of the air and gas supply, but it is most desirable that glass manufacturers should realise that different clays require different treatment in the firing-up process.

Let us assume, however, that a firm does realise that different heat treatment is necessary for different clay mixtures, and erect a pot arch in which the temperature can be controlled. There still remains the difficulty of obtaining essential information regarding the correct heat treatment for the pot clay mixture to be given a trial. Each glass works cannot be expected to carry out a research to ascertain the facts, whilst at present most of the clay firms do not show any eagerness to ascertain and hand on the particular facts required. In the circumstances we must look to scientific workers in general, and in particular to trade research associations, to help us. The paper before us is welcome, as from it the glass manufacturer learns that men of science are appreciating and tackling such problems. I trust that this paper is only the first of many. We must not forget that similar work is being done at Sheffield University, but many more helpers are desired. The scientific worker may in turn ask how a glass manufacturer treats a pot, and what information is required. The old type of pot arch does not go much above 1000°, and therefore during pot setting the pot is in a biscuit condition. So long as we do not pass this stage, the pots appear to stand a very considerable drop in temperature without damage, and in such a case the maturing of the pot clay is completed in the furnace.

Where a modern type of gas-fired pot arch is used, however, much higher temperatures are obtained, and the pot is past the biscuit stage when set. This sets up a different problem, for if the temperature drops below some definite point, failure occurs. Various types of furnaces have the same problem. In order to avoid this trouble, we should know approximately the temperature at which the biscuit stage is finished and that at which there is danger of failure.

In the early stages of arching we want to learn the most suitable rate of temperature increase for each pot clay mixture.

Let us consider what is the treatment of the pot when in use. Let us assume that a pot is at the gathering temperature (1100°) after the blowers have finished work. The gas is turned on full and the whole furnace heated up quickly; more batch and cullet are thrown in, leading to a very considerable and sudden drop in the temperature of the pot. A few hours afterwards more batch and cullet are thrown in, the temperature rising to a maximum, after which the whole furnace is cooled off, to be ready once more for gathering. Generally there is a rush to cool off the furnace in time. At times local changes of temperature occur. If at any of these temperature changes the critical temperature for the particular clay mixture in use should be approached nearly, there would ensue serious risk of failure. We must look to the men of science to ascertain these danger points; but until this knowledge is available we cannot place our furnace and pot problems on a scientific basis. In the meantime, by careful observation and record keeping, we can make progress. When the information is available it will be the glass manufacturer who has his pot arch under control with recording pyrometers installed who will reap the benefit.

In conclusion, I would say to men of science that if when visiting a glass works they would spend the night there instead of the day, they would learn more and realise how high are the temperatures at which modern furnaces are worked during the founding period.

Mr. E. A. Coad-Pryor said that in the study of refractory materials there was probably a greater need of fundamental work on physical constants than in any other branch of applied science, and Prof. Cobb's paper was a welcome addition to our literature.

The value of the data given in the paper would be greatly enhanced if test-pieces of the materials examined, fired to a higher temperature, say cone 12 or 14, had been included in the experiments, and he hoped that Prof. Cobb would see his way at a later date to amplify his results in this way. It was rather probable that, on higher burning, the curves for the fireclay and glass-pot mixture would straighten out in a manner similar to those shown in Fig. 5. This was of course an important point in practical application, particularly in the case of glass pots, which, as a rule, had (or ought to have) been heated to a temperature higher than that indicated by cone 9 before setting. So far as he recollected, Boeck gave curves for a ball clay and a fireclay which did not show an increase of coefficient of expansion in the neighbourhood of 550°. His specimens were burnt to cone 12. However, no analyses of Boeck's samples were given, and so the results were difficult to interpret.

It would be useful to those working on physical constants to have figures for the authors' blank run, in order to obtain some idea of the degree of precision to be expected from this method of measurement of the coefficient of expansion.

There was something to be said for the use of a graphite tube and graphite distance pieces instead of quartz; the graphite would not burn seriously if suitable precautions were taken. The experiments could then be carried to a higher temperature if desired. (Day and Sosman determined the expansion of graphite to 1500°.)

It would be interesting to know whether refractory materials, when near their softening points, exhibited that marked increase in coefficient of expansion which was said to exist in glass in the annealing range.

Mr. W. J. Rees said that the paper would be of considerable interest to all users of refractories. It emphasised the need for extreme care in the heating up of any furnace containing silica or fireclay bricks. The rapid increase in the rate of expansion of silica between 550° and 600° also emphasised the great importance of close attention to the furnace tie-rods as the furnace reached that temperature range. Several of the experimental results were of very great interest, and reference to them was desirable. The curve for kaolin showed no indication of the presence of quartz in the burned sample used; it had been generally considered that at temperatures just above 500° kaolin decomposed into Al_2O_3, SiO_2, and H_2O, and that at temperatures above 1200° the Al_2O_3 recombined with a portion of the SiO_2, forming *sillimanite.* It would therefore be expected that in the kaolin sample burned at 1280° there would be some free silica. As the temperature–volume curve showed no indication of the presence of quartz, it was possible that this free silica was present as *tridymite.* The α to β inversions of *tridymite* occurred at 117—163°, and the accompanying volume change was a much smaller one than the α—β inversion in quartz. The same reasoning would apply to the change in the character of the curve for ball clay when samples previously burned at 980° and 1280° were compared. The inversion of *quartz* to *tridymite* was accelerated in the presence of fluxes such as are present in the ball clay, as indicated by the analyses, and it was therefore probable that the suppression of the volume change at 550—600° was due to the transformation of the whole of the silica to *tridymite.* This would incidentally confirm the important point that the α—β volume change in *tridymite* was a very small one. It would be useful if the volume porosity of the samples used was added to the tables, as possibly some of the anomalies might be explained by variations in this factor. The possibility of this was referred to by the authors in connection with the clay–silica test-pieces. The behaviour of the silica test-piece was interesting, and the absence of any indication of inversion of *quartz* to *tridymite* emphasised the extreme sluggishness of the silica inversions in the absence of fluxes. In any case, even in the presence of 2 per cent. of lime, the inversion at the temperatures of the tests would be extremely slow. It was possible that some *tridymite* was formed in the initial burning of the sample to 1280°, but, as before suggested, this would not be evident on the temperature–volume curve. A determination of the specific gravity of the specimen would be of interest, as this would indicate whether or not inversion of the *quartz* had taken place to any extent. The further work referred to by Prof. Cobb as being in progress would be awaited with interest, particularly that on commercial samples of silica brick. If the α—β volume changes of the polymorphic forms of silica were, in order of degree or extent of expansion, (1) *tridymite,* (2) *quartz,* and (3) *cristobalite,* it followed that a silica brick containing the bulk of its silica in the form of *tridymite* would be less susceptible to temperature fluctuations than one containing either (or both of) *quartz* or *cristobalite*, and would have only a small permanent after-expansion. It would therefore be advantageous if the authors would, in this further work, determine to what extent the *quartz* in the samples to be tested had been transformed into *tridymite*.

Mr. J. Holland thanked the authors for their very valuable paper. They had demonstrated particularly two points, the importance of which he thought had not hitherto been generally appreciated, and which suggested scope for further research, namely, first, that the contraction on cooling silica and clay just below 600° exceeded the corresponding expansion on heating, and, secondly, that in a mixture of fireclay and added silica (No. 2, Fig. 4) the curve from just under 600° upwards was almost identical with that from a silica brick. The regular, steady curves in Fig. 6 of alundum, carborundum, and magnesite were what one would expect considering that each of the materials from which the test-pieces were made had previously been sintered at a very much higher temperature than in any of the other tests. In the silica test-piece, which had previously been slowly burned at cone 9 (approximately 1280°) for more than seventy-two hours, and afterwards tested to 1000°, he was rather surprised to find that no inversion to *tridymite* could be detected, the only change being from α-quartz to β-quartz. In spite of the diversity of opinion as to the temperature at which *quartz* became inverted to *tridymite*, he would fully expect to find some inversion after the original burning to cone 9. It would be interesting to compare the curve, obtained under the same conditions, of a commercially made silica brick which had been burnt at a higher temperature than cone 9, say cones 13—14, and in which the silica would, to a certain extent, have become inverted.

As the present-day tendency of most furnace practice was to work at higher temperatures, he was very pleased to hear from Prof. Cobb that he contemplated carrying forward experiments on similar lines to higher temperatures, say 1400°. These results would be looked forward to with the utmost interest, and would materially enhance his present most valuable contribution.

Mr. W. J. Gardner referred to the fact that it was not unknown that considerable expansion took place in silica bricks at low temperature. Some comparative, if crude, tests had been made in the past during the actual burning of refractories in the kilns, and many an old burner knew that much "contraction" took place below a dull red heat through the continual crackling distinctly audible at and below that point.

Much attention had been directed to this matter by the American observers, notably by Ross,* who showed a lineal expansion under load of 0·363 per cent. at 650°, rising only to 0·408 per cent. at 1200°, which practically coincided with the authors' results.

It would be interesting and valuable to have these tests carried to a higher temperature, and tabulated with the porosity, specific gravity, and percentage increase in volume of the refractory.

The matter contained in the paper should be of great value in impressing upon manufacturers, not only the importance of special care in firing at certain temperatures, but also to operators of all classes of furnaces the importance of heating up very slowly from dead cold constructions where such refractory materials were used. Many such structures had been spoilt by want of more care and better knowledge of these expansions, resulting in spalling and destruction of the lining, for which the manufacturer has been too often blamed.

Mr. G. V. Wilson stated that he was greatly interested in the work of Mr. Hodsman and Prof. Cobb. There were, however, one or two points that were not quite clear; for instance, the silica curve showed a slight contraction on approaching 1000°, and a similar contraction in the case of alundum. The only reason that he himself could suggest was that, as a certain amount of glass was present in both cases, a little devitrification had taken place, in the first case with the formation of *tridymite*, and in the second of *corundum*. He would also like to point out that *alundum* must not be regarded as a homogeneous glass, but as an almost completely devitrified glass packed with crystals of *corundum*.

The curves for fireclay showing the influence of silica on kaolin were interesting, and it would be of value to have similar curves made with mixtures of kaolin with 5, 10, 15, 20, and 25 per cent. of added silica. By comparing such curves with that of any clay, it would then be possible to estimate approximately the amount of free silica present in it.

The straight line curve for the Ayrshire bauxitic clay, "indicating the absence of free silica," corroborated the microscopic examination of the material, since no free silica had been seen in any slides of material containing more than 40 per cent. of alumina.

Dr. M. W. Travers considered that Prof. Cobb's experiments probably covered almost the complete range at which expansion of fireclay materials could be considered as reversible, unless the heating was of very short duration, a condition which was scarcely worth considering. A point of considerable interest was the very slight differences between the ultimate expansion of most of the materials investigated between 0° and 1000°, the difference in the expansion of 6-foot lengths of carborundum, fireclay, and silica between these temperatures being only 0·15 inch. This point was of great interest to those concerned in the construction of recuperators and other parts of furnaces where the temperature did not exceed 1000°, but where leakage of gas was to be avoided. The study of silicious firebricks, which had not received the attention in this country from the glass industry which they deserved, might be carried further to cover mixtures with less silica. Contributions to our exact knowledge of refractories such as this were of very great value to the industry.

---

* *J. Amer. Cer. Soc.*, 1918, **1**, 477.

Prof. Cobb, in reply, said it was very gratifying to learn from the discussion and comments to which the paper had given rise that the importance of the subject dealt with was appreciated both on the more purely scientific and on the practical side, and that the work described was believed to be of service. Mr. Jenkinson had indicated the amount of work on this and parallel lines which was waiting to be done, and the extent to which scientific investigation in the laboratory and exact observation in the works would both be called upon if effective solutions of manufacturing problems are to be forthcoming. The authors quite realised that what they had published was only a beginning of what was necessary before technologists could regard themselves as reasonably well informed as to the behaviour in this respect of refractory materials. They have already carried out further work on various forms of silica and clays which had given interesting additional information, and they had tested specimens fired to higher temperatures. The results would be dealt with in a later communication. To that extent certain criticisms had been anticipated. They would like to express their satisfaction of the appreciative and helpful way in which, without exception, the criticisms received had been expressed. These would be dealt with in turn.

They could not altogether agree with Mr. Coad-Pryor that the coefficient of expansion recorded by Boeck showed no variation in the neighbourhool of 550° with samples of ball clay and fireclay. Boeck's curve for the fireclay showed an irregularity at this point, although much smaller than that recorded by the authors. The rapid rate of heating (20° per minute) may have contributed to the suppression of discontinuities in his curves. They agreed that the absence of some indication as to chemical composition detracted very seriously from the value of his results and prevented useful interpretation and comparison. The observed changes of length of a fused silica specimen 20 cm. long used in the blank determinations were as follows:—100°, $<0·01$ mm.; 200° to 500°,

<0·001 mm.; 600°, 0·01 mm.; 700°, 0·015 mm.; 800°, 0·025 mm.; 900°, 0·03 mm. These could be plotted in any of the diagrams given, one division of which corresponded with an expansion of 0·1114 mm. on a specimen 20 cm. in length. These figures could be compared with those indicated by the curves, and such comparison showed the smallness of any "blank" correction. The authors thanked him for his suggestion as to the possible usefulness of graphite at higher temperatures.

Mr. Rees discussed the curve for kaolin in relation to the view that kaolinite was decomposed to Al_2O_3, SiO_2, and H_2O at 500°, followed by recombination to form *sillimanite* above 1200°. If this were so, then the kaolin specimen (cone 9) should contain free silica. Whilst their observations did not counter this theory, they did not provide any support for it or for the analogous theory of the formation of *allophane* and free silica. The behaviour of different forms of silica was so diverse that great caution was necessary in accepting any views of its transformation which might be held. They (the authors) had also found evidence of the influence of porosity on dilatation, and that emphasised the suggestion of Mr. Rees and Mr. Gardner that the fullest evidence of physical and chemical properties was desirable in interpreting the curves. They would try to remedy the defect.

With regard to Mr. Holland's view that the regular expansion of alundun, carborundum, and magnesia was due to the high temperature of calcination, this was only partly true. It was more probably a specific property of these substances. Experience with silica brick material heated to temperatures above cone 9, but short of fusion, showed that the discontinuities in its expansion were by no means eliminated, although they were undoubtedly transferred to other temperature ranges.

Turning to Mr. Wilson's suggestion about the slight contraction of silica at 1000°, they did not think it wise to attach too much importance to this. It might be associated with the corresponding contraction of the blank as indicated in the text, and now in more detail in reply to Mr. Coad-Pryor. Mr. Wilson's suggestion as to the use of these curves for determining the properties of free silica in clay mixtures was interesting, but in view of the possible incidence of such factors as porosity, caution would be necessary in application. The authors were pleased to note that microscopic evidence supported the results on the Ayrshire bauxitic clay.

Dr. Travers rightly pointed out that exact reversal on cooling of an expansion on heating may be conditional on the ranges of temperature in question. It might be influenced by the changes which came into prominence at higher temperatures, some chemical and some physical as the temperature of fusion was approached. Mr. Coad-Pryor's comment directed attention to this also. In their experiments, however, the test-piece had always been heated for a considerable period at temperatures well above the range for which expansion and contraction were being taken, and so very approximate reversibility was secured.

XX.—*The Properties of the Lime-soda Glasses.*

By J. H. Davidson, M.Sc., and W. E. S. Turner, D.Sc.

(*Based on a Paper read at the Leeds Meeting, November 20th,* 1918.)

The glasses of which sand, lime, and soda are the chief components are by far the most important in commerce, and for this reason several studies have previously been made of some of their properties. In previous papers published from this Department, particularly in respect to the durability of glass, some information has been forthcoming both in regard to the effect of lime and of certain other constituents.

When, however, one examines the literature of glass, it is obvious that many of the deductions concerning the effect on the properties of glass of its constituent oxides have been made from a study of very heterogeneous glasses, rendering conclusions difficult to make in the first place, and very liable to criticism with every new investigation.

For example, in regard to chemical resistance, it has been possible in previous communications from these laboratories to illustrate the effect of certain of the oxides in influencing durability, but the variations of composition were so irregular in the available glasses that it was impossible in certain cases to decide the actual function which some of these oxides exerted.

Further, when one studies the lists of glasses which were made the basis of the classical studies by Schott, Winkelmann, and others, one finds them in most cases so complex that one wonders how far the conclusions derived from them, conclusions which appear to make it possible to calculate, from the composition, such properties as density and coefficient of expansion, can be regarded as trustworthy.

In our opinion, the only trustworthy method of determining the specific effect of the various constituents which enter into the composition of glass is to start from the simple and work to the complex; that is to say, one should first study a series of glasses in which the components are restricted to two in number, and having ascertained the effect of these, to add in turn a third, fourth, fifth, and so on constituent. Only by proceeding in this systematic, even if slow, method can a thorough knowledge of the behaviour of glass be gained and the properties of any new glass be capable of prediction.

With these considerations in view, a series of systematic inquiries has been begun of the properties of glasses and their dependence on the composition. The commercial importance of the lime-soda glasses naturally suggests them as the first type for study.

Already a brief communication has been made on the upper annealing temperature required for lime-soda glasses of varying composition. This paper furnishes the further information promised in regard to the preparation of the glasses used. The opportunity is also taken of making a few comments which our experience warrants us in hoping will be of service to the general body of manufacturers.

It is possible to build up glasses containing silica, lime, and soda in almost any conceivable proportion providing one has sufficient melting power. Hitherto, however, commercial lime-containing glasses have usually been found to be successful if their composition can very approximately be expressed by a certain chemical formula, namely, $6SiO_2,CaO,Na_2O$, in which the proportions of lime and of soda may be varied, still retaining the relationship, however, that there shall be three molecules of silica to one molecule of the lime and soda combined.

Since this is so, most of the glasses which were prepared for initial study may be represented according to this general formula. At some later date we hope to be able to communicate results concerning lime-soda glasses in which the proportions vary from those given above. Table II contains the compositions of the glasses used when stated according to their approximate chemical composition. As this, however, will only be understood by the technically equipped person, and not by the general manufacturer, the actual batch mixtures from which the glasses were prepared are given in Table I.*

---

* [In Table I, one of the simple methods of setting out batch compositions is followed, namely, that of stating the sand as the fixed quantity, either 100 parts or 1000 parts. It would make for simplicity if manufacturers would follow a similar method, expressing their batch compositions in terms

TABLE I.

Table of Batch Compositions.

No. of glass	1	2	3	4	5	6	7
Sand	1000	1000	1000	1000	1000	1000	1000
Soda ash	590	560	530	501	471	441	412
Limespar	—	28	55	83	111	139	166
Arsenic	—	—	—	—	—	—	—

No. of glass	8	9	10	11	16	17
Sand	1000	1000	1000	1000	1000	1000
Soda ash	383	353	324	294	365	285
Limespar	194	222	250	278	500	450
Arsenic	—	—	—	—	7	7

Thirteen glasses were studied, and of these, Nos. 1—11 follow the chemical formula mentioned above. Nos. 16 and 17 are glasses which have been in actual commercial use for the purpose of bottle manufacture. They do not follow the above chemical formula, the actual formula being noted in Table II.

The materials employed were of the best type supplied in bulk for glass-making. The sand employed was Fontainebleau. The limespar per 100 parts contained 0·61 of silica, 0·05 of Fe_2O_3, 0·08 of Al_2O_3, 0·31 of MgO, and 55·43 of CaO. The soda ash contained 1·0 per cent. of sodium chloride and 0·17 per cent. of sodium sulphate. It also contained 5 per cent. of moisture, but the figures given in the table have been calculated to the basis of dry soda ash, so as to be readily understood.

of pounds, and using, for example, 1000 lb. of sand as the basis instead of the very mixed system of units, in which tons, cwt., and stones all figure.

An alternative system, which requires knowledge of the elements of chemistry, however, is to set out the batch quantities which will produce actually 100 units or 1000 units of melted glass. This would mean that the amount of batch necessary would be in excess of 100 or 1000, as the case may be, and in order to calculate it, a knowledge is required of the amount of the loss which each of the constituents sustains when fused up in the furnace. For any successful system of glassworks costing, these losses ought to be known. It may be useful to state that the following are the percentage proportions of various constituents which are left behind in the glass after fusion has occurred.

Sand	100·0	Limespar	56·0
Soda ash	58·5	Slaked lime	74·0
Saltcake	42·5	Red lead	97·7
Soda nitre	36·5	Litharge	100·0
Potash nitre (saltpetre)	47·0		

These figures, of course, assume that the materials are dry, and reasonably pure. Only chemical analysis of the sample can furnish the precise figures. There will also be very slight losses due to volatilisation of soda, for example, but these losses are small and depend on the type of furnace, mode of melting, and time.]

TABLE II.

Table of Working Properties.

Glass No.	Approx. molecular composition.	Remarks on working properties.	Remarks on lampworking property of glass.
1	$2Na_2O,6SiO_2$	Very fluid at 1100°. Could be worked at 850°.	Very soft—almost watery. Readily devitrified.
2	$1{\cdot}9Na_2O,0{\cdot}1CaO,6SiO_2$	Worked well over the range 1100—850°.	Very soft. Not so readily devitrified as (1).
3	$1{\cdot}8Na_2O,0{\cdot}2CaO,6SiO_2$	Worked well over the range 1100—850°.	Very soft. Easily devitrified.
4	$1{\cdot}7Na_2O,0{\cdot}3CaO,6SiO_2$	Worked well at 1100°. Too viscous to work at 900°.	” ” ”
5	$1{\cdot}6Na_2O,0{\cdot}4CaO,6SiO_2$	Too viscous at 900°.	Appreciably stiffer than 1–4 when hot. Easily devitrified.
6	$1{\cdot}5Na_2O,0{\cdot}5CaO,6SiO_2$	Worked out between 1100° and 950°.	Works almost normally. Less easily devitrified.
7	$1{\cdot}4Na_2O,0{\cdot}6CaO,6SiO_2$	Worked out at 1050°.	” ” ” ”
8	$1{\cdot}3Na_2O,0{\cdot}7CaO,6SiO_2$	Worked well between the temperatures 1050° and 1000°.	Works normally. Becomes devitrified differently from No. 7.
9	$1{\cdot}2Na_2O,0{\cdot}8CaO,6SiO_2$	Viscosity increased rapidly on cooling.	Works normally. Hardens, due to devitrification.
10	$1{\cdot}1Na_2O,0{\cdot}9CaO,6SiO_2$	Worked well at temperatures between 1350° and 1100°.	Normal until devitrified, then hard and incapable of being joined to same glass not devitrified.
11	$1{\cdot}0Na_2O,1{\cdot}0CaO,6SiO_2$	Worked well at 1200°. Viscosity increased rapidly with falling temperature.	As (10), but not so quickly devitrified.
16	$0{\cdot}81Na_2O,1{\cdot}18CaO,3{\cdot}94SiO_2$	Very fluid at high temperatures, 1250—1400°. Difficult to work on account of rapid increase in viscosity on cooling.	Devitrifies, but not readily. Harder than ordinary lampworking glasses.
17	$0{\cdot}75NaO,1{\cdot}25CaO,4{\cdot}63SiO_2$	Metal very fluid at 1400°. Difficult to work on account of rapid increase of viscosity on eooling.	Better than any of preceding glasses.

The melting of the batch was carried out in a gas-fired furnace in covered pots of approximately 28 lb. capacity. In one or two cases 56-lb. pots were employed. As a result of a considerable number of tests, we find that it is by no means easy to fine glass in the 28-lb. size unless it is soft, but quite good results are obtained with the larger pot, and in all the experimental work subsequently undertaken this has been the minimum size of melt which has been made.

The difficulty of knowing when a pure product has been obtained in the case of an amorphous substance is well known to chemists and to those manufacturers especially who prepare optical glass. In the case of materials which crystallise, it is always easy to repeat the process of crystallisation until a pure product, as tested by constancy of melting point or some other property, is obtained. In the case of glass, however, the only thing that can be done is to be sure that it is thoroughly well stirred in order to produce homogeneity and to test different samples of the product so as to make certain that the properties are the same throughout. This process was adopted in the present case, and measurements made on different portions of each glass of the density and of the refractive index. Only slight variations in the fourth place of the refractive index for any one type of glass were found, and in the case of density the results agreed to a unit in the third decimal place.

The glass when ready was, as a rule, worked out into a form of glass tubing, glass rod, and of discs cast in moulds about 6·5 cm. in diameter.

The actual composition of the different glasses prepared is shown in Table III. In Nos. 6 and 7 there were present amounts of iron oxide greater than desired, and in the case of No. 6 some must have been accidentally introduced. The presence of this amount of iron and the corresponding amount of alumina did not appear, however, on the result of test, to cause any noticeable effect, either on the durability or on any other properties so far measured.

In Table II some data are given in regard to the working of the glass in the molten state, and also its behaviour when heated in the lamp. The working character of the glass was determined from its behaviour when gathered and marvered by an experienced workman. Naturally, the cooling effect of the ordinary sized blowing iron on a gathering from a small pot would be greater than on that from a large-sized pot, and this must be borne in mind when considering the comments. Nevertheless, the facts have a relative, if not an absolute, value.

It is not to be imagined that the simple lime-soda glasses are really satisfactory for lampworking purposes. It is interesting to note, however, that whilst lime-containing glasses have usually been regarded as readily devitrified, in the above series devitrification took place less and less readily as the amount of lime increased. It will be noted, indeed, that in glasses 16 and 17, containing high proportions of lime, the tendency to devitrification was least.

TABLE III.

Composition of the Lime-soda Series of Glasses.

Glass.	SiO_2.	Na_2O.	CaO.	MgO.	Al_2O_3.	Fe_2O_3.	As_2O_3.	Total.
1	74·05	25·34	0·21	tr	0·24	0·14	—	99·98
2	73·92	23·80	1·50	tr	0·20	0·14	—	99·56
3	74·08	23·00	2·61	tr	0·21	0·15	—	100·05
4	74·07	21·50	3·81	tr	0·28	0·14	—	99·80
5	73·78	20·78	4·50	0·15	0·38	0·19	—	99·78
6	73·18	19·38	6·26	0·21	0·58	0·61	—	100·22
7	74·41	17·20	7·45	0·24	0·30	0·40	—	100·00
8	74·99	16·00	8·16	0·26	0·31	0·09	—	99·81
9	74·96	14·88	9·36	0·28	0·42	0·16	—	100·08
10	74·59	14·22	10·38	0·30	0·45	0·21	—	100·15
11	74·93	13·02	11·68	0·31	0·38	0·17	—	100·49
16	66·71	12·72	18·17	0·85	1·41	0·31	0·30	100·47
17	69·73	11·22	17·38	0·55	0·50	0·25	0·47	100·10

As the result of our study of these glasses, we would note that all glasses of composition 1 to 6 should be avoided. From 7 onwards, there is a general improvement, and glasses 7 to 11 are all durable, as will be seen from a succeeding paper.

For the purpose of semi-automatic machines, glasses of the composition between those of 7 and 9 are most suitable. This does not mean to say that the simple batch compositions indicated may be the most satisfactory, but that they may be used as a basis to which small amounts of other batch materials may be added. We should, for example, recommend, in the case of glass 7, that the amount of sand should be increased somewhat, whilst in all of them an amount of alumina introduced as felspar, china clay, or ground brick, dependent on the type of glass to be produced, should be added.

For pot metal, these same remarks hold good, namely, that glasses 7 to 9 will usually be found satisfactory.

Glasses 10, 11, 16, and 17 are more suitable for working in tanks operated by hand labour. The metal produced in each case sets rapidly, and is therefore better adapted for making moderately large bottles by hand than is the glass made from batches 7—9.

DEPARTMENT OF GLASS TECHNOLOGY,
THE UNIVERSITY, SHEFFIELD.

XXI.—*The Durability of Lime-soda Glasses.*

By J. D. Cauwood, M.Sc., A.I.C., J. R. Clarke, M.Sc., Constance M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

(*Read at the Sheffield Meeting, February*, 1919.)

It has previously been remarked in communications from this Department that it is useless to spend time in manufacturing a glass if that glass when made is unable to withstand the action of the air or the action of the materials which are destined to be placed in it.* However obvious this remark may seem to many, it nevertheless requires to be made, and to be emphasised, judging by the occasional experiences which we meet with.

Fig. 1 illustrates in a very practical manner the point at issue. It is a photograph of a piece of commercial lime–soda glass which came to us for test, since it had been found, when kept in store, to get covered with a white film. After being subjected to the action of water at 120° for three hours, it presented a pitted or mouse-bitten appearance, whilst a series of cracks developed throughout its body.†

We have also had to deal with bottle glass exhibiting a similar failing, whilst in another case a feeding bottle, when boiled for the purpose of sterilising it, developed a similar appearance to that shown in Fig. 1.

The introduction of the new types of automatic machinery has called for a moderately soft glass. This condition has been obtained by decreasing the amount of lime and increasing correspondingly the amount of soda present. It is essential to determine once for all how far this softening process may proceed, so as to set the limits between which durable commercial glasses may be prepared. This is the whole object of the investigation recorded in this paper.

The compositions of the glasses tested have been recorded in a preceding paper.‡ For manufacturers whose technical knowledge does not enable them to grasp the bearing of the chemical analysis, the results should nevertheless be quite clear and plain, because the batch compositions are also given.

---

* See, for example, "Bottle Glass and Glass Bottle Manufacture," W. E. S. Turner, D.Sc., this Journal, Trans., 1919, 3, 37.

† The prominent radiating markings are flutings cut in the glass.

‡ This vol., Trans., p. 227.

228

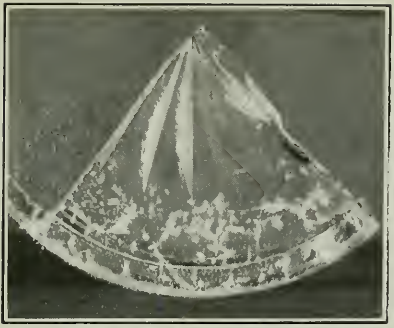


FIG 1.

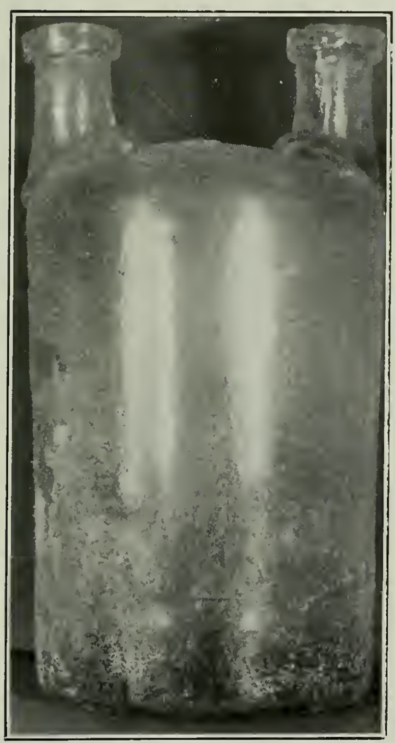


FIG. 3.

[*To face p.* 228.

The Tests adopted to determine Durability.

Of the various materials which may be charged into bottles, some may be quite without action on the glass, such as perfectly dry solids and also oils. Acids, alkaline liquids, and aqueous solutions all may possibly prove corrosive. Hence, it is necessary to test the action of water, of acids, and of alkalis on the glass.

In most of the tests which have previously been carried out in the Department, we have had to deal with chemical apparatus, such as flasks and beakers, and the determination has been made on the flask or beaker itself. The object of this was to follow as closely as possible the methods of earlier investigations, and so enable us to make comparisons.

It was not long, however, before we found ourselves criticising such methods of test. It is quite true that it is possible to get comparable results by repeating the tests on flasks of any one type. Nevertheless, there are certain important objections to the method.

In the first place, we have found that the shape of the vessel has by no means an unimportant influence on the result obtained. Thus we have frequently found, especially with the hydrochloric acid tests, that the results for flasks and beakers do not agree. With reagents used at the boiling point there are two separate factors to consider. There is first of all the action of the liquid on the glass, and, next, there is the action of the vapour (steam or hydrochloric acid, for example) on the upper surface. In the case of a beaker, more of the vapour can escape without exerting any influence on the surface of the vessel than is the case with the flask. Moreover, we have found that water and steam play quite different parts according to the composition of the glass. In a communication which we hope to make shortly we shall show that in some cases, especially in some types of lime–soda glass, steam is much more damaging to a glass than is liquid water itself.

There are also other objections; for example, the test with alkalis is usually carried out by placing a vessel with its solution in a thermostat, that is, some arrangement which automatically maintains the temperature constant. In this process the liquid in the flask remains quiescent, and the action of the alkali on the particular glass will depend on the rate of diffusion of the dissolved matter away from the surface of the glass. It is an axiom in chemistry that two substances which are undergoing mutual action shall be mixed as thoroughly as possible. If this is unattainable, as in the case of a gas or liquid acting on the surface, it is essential that fresh liquid or gas shall continuously be brought in contact with the surface. The method of testing glassware just mentioned does not permit of this.

We have therefore attempted to make the methods of test first of all simpler, so that they can in many cases be undertaken in any works laboratory, and, secondly, we have attempted to remove some of the objections mentioned above. In the first place we have employed the glass in the form of pieces of simple, regular shape, the whole surface of which could be submitted separately to the action of liquid or of vapour as desired. The pieces tested were discs made by a casting process, having a diameter of approximately 6·5 cm. Secondly, the discs were wholly immersed in the liquid in a boiling condition, which ensured thorough mixing of the corroding liquid. In other tests (not now reported) the discs were submitted to the action of steam at a constant temperature.

Following on these lines, we have tested the action of boiling water, boiling hydrochloric acid of constant boiling strength (20·24 per cent.), $2N$-caustic soda, and $2N$-sodium carbonate. These reagents were selected from amongst the larger number previously employed in connection with the tests on chemical ware as being the ones of real importance. The treatment with water and with hydrochloric acid was for a period of six hours, with the other reagents three hours.

The Apparatus Employed.

The discs of glass were suspended in a large beaker containing the reagent. Three different types of vessel were employed, namely, resistance glass, fused silica ware, and silver. Fig. 2 shows the general arrangement. In early experiments, the disc was suspended by carefully washed out string. In later experiments, however, a carrier of silver wire was specially made for the purpose of suspending the discs. On the top of the beaker was placed a platinum, or silver, or silica ware basin, containing cold water, supplied from a tap, and exhausted by a syphon. By this means any evaporation of the liquid in the beaker was prevented.

Silica ware was employed for the water tests, the silver beaker for the tests with the alkali. It must be noted, however, that the silver beaker had not been obtained before most of the tests of the alkalis given in this paper had been carried out, and a resistance glass vessel made of the composition given in a previous paper was used.* The attack which alkalis have on this glass (glass F) had previously been determined, and was found to be exceedingly small and quite negligible compared with the actual strength of the alkali employed.

---

* This Journal, Trans., 1917, **1**, 153.

Although the results are finally summarised for discussion later, there are various details which must be quoted at length.

The Action of Water.

Glass No. 1, containing no lime, proved difficult to test. Several discs fell to pieces as the result of cracks. The great loss in weight sustained by the action of water was largely due to the shattering of the glass surface, fairly large pieces cracking off. At the end of the six-hour boiling, the water was strongly alkaline and contained much solid matter. It will be noted from the table (p. 235) that strong alkali has a much smaller action on the glass than has water, so that the figure given for the effect of water is probably an underestimate. Moreover, it must be noted that with glasses 1, 2, and 3 a correct determination of loss of weight was impossible. As soon as the disc was dried, additional flakes developed in its surface,

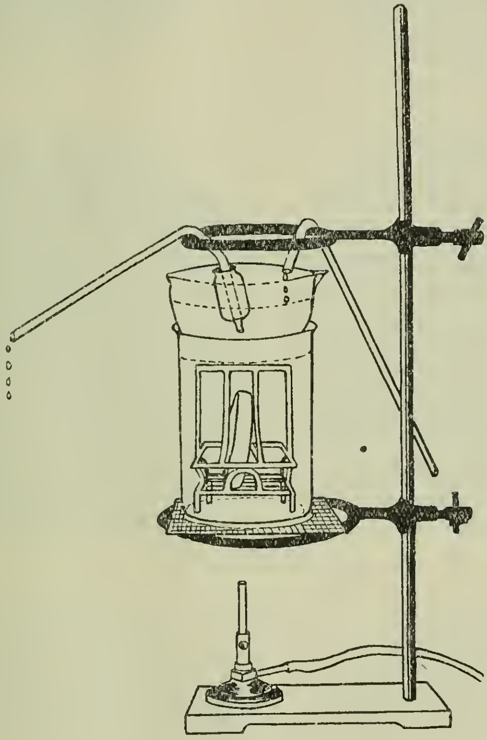


FIG. 2.

and successive dryings were followed by further flaking. The weights recorded are those after the first removal of flakes, that is, after the first drying.

This surface flaking has been observed by the authors with a poor quality German Woulfe's bottle (and occasionally with other ware) containing too much soda and too little lime. After being washed and dried in a steam oven, its surface assumed a frosted appearance, as seen in Fig. 3.

Figs. 4 and 5 are photomicrographs of different portions of the surface of the disc magnified 30 diameters. These indicate extensive attack all over the surface, but scarcely adequately represent the very great degree of corrosion occurring, the surface being pitted with holes up to 1·5 mm. deep.

Glass No. 2 yielded very small flakes to the water, and its surface was, as seen by the naked eye, covered with fine cracks. On close examination some of these cracks were 1 mm. deep and often started from pits or holes. Fig. 6 shows one such hole and the general surface appearance.

Both in glasses Nos. 1 and 2 the attack of the water appeared to have a selective action. In casting the discs the glass was gathered and poured from a gathering iron. When settling into the mould, the waves of the glass do not appear to have been entirely eliminated, as is evident from the fact that attack appears to take place along the lines which bounded the waves of glass.

Glass No. 3 exhibited no selective attack, and its surface, as shown in Fig. 7, had a pattern somewhat similar to that of glass No. 2 (Fig. 6), except that the markings were less prominent.

Glass No. 4 shows decreasing attack with increase of lime content, the surface markings (Fig. 8) being much less prominent.

Glass No. 5, when removed from the water, showed signs of surface cracks, but did not flake on drying. Under a magnification of 1000 diameters it did not reveal any etching. Several small pits were noted, however, in the surface of the disc.

Glass No. 6, after six hours' boiling, exhibited very few cracks of a very slight character only. All other glasses examined showed no signs of attack.

In addition to the results of the tests of boiling the discs, further evidence of the suitability or otherwise of the glass for commercial use was readily indicated by its behaviour when very finely powdered. Samples of the different glasses were reduced to a very fine powder for the purpose of analysis, and it was found that all of them, from Nos. 1 to 6 inclusive, took up moisture in that condition, so that it was necessary to dry them carefully by gentle ignition before the analysis could

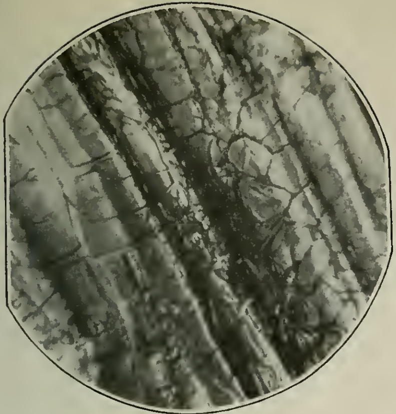


FIG. 4.

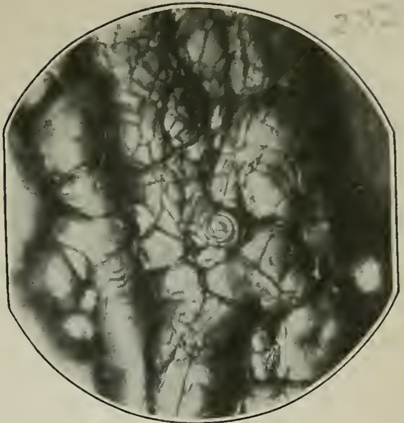


FIG. 5.

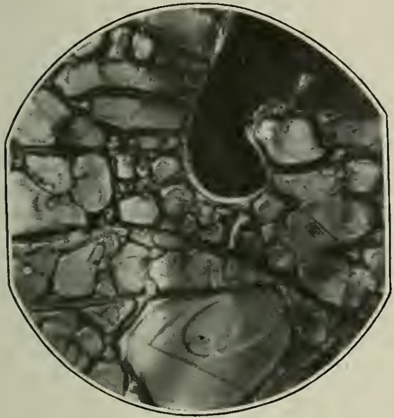


FIG. 6.

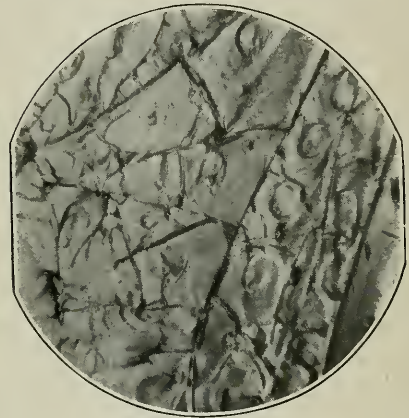


FIG. 7.

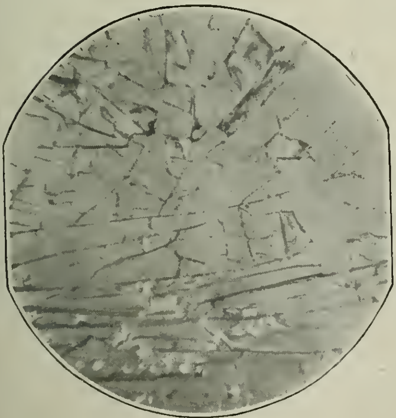


FIG. 8.

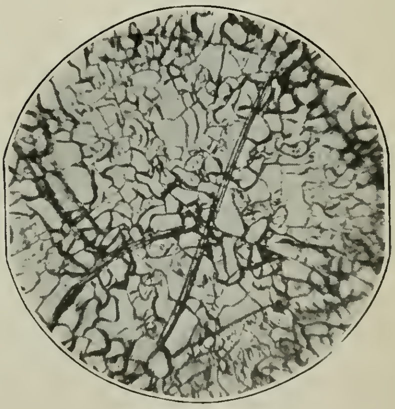


FIG. 9.

[*To face p.* 232.

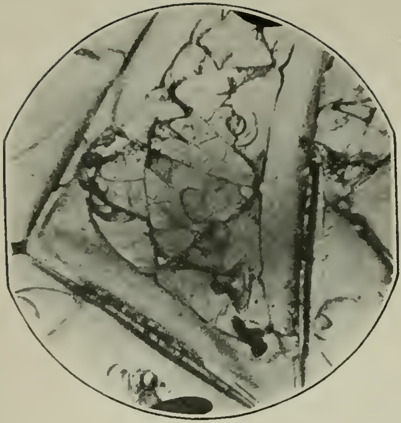


FIG. 10.

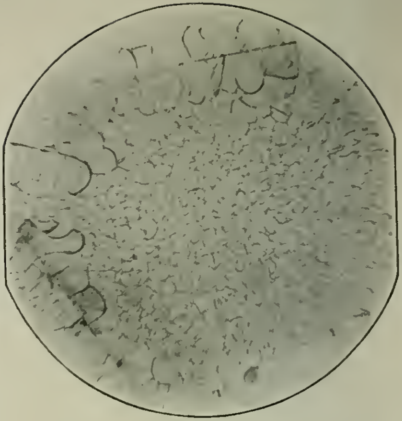


FIG. 11.

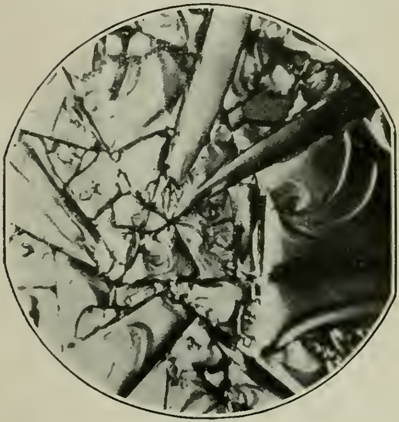


FIG. 12.

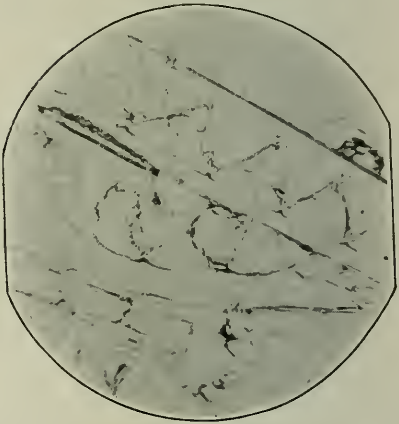


FIG. 13.

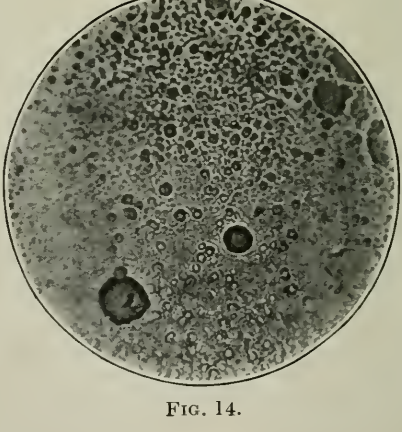


FIG. 14.

be proceeded with. The hygroscopic character diminished, as will be expected, from glass 1 to glass 6, but it was still appreciable with this last-named glass, indicating that glass No. 6 likewise should be considered as outside the limits for commercial use, although the degree of attack, as indicated by the figures in the table, is perhaps not excessively high.

The Action of Hydrochloric Acid.

In carrying out the tests with hydrochloric acid, care was taken that the boiling point of the solution should remain as constant as possible. As a matter of fact, the variation of the boiling point throughout the series did not amount to more than approximately 0·5°, the recorded temperatures of the boiling point varying from 108·4° to 108·9°, this variation being accounted for mainly by difference in the barometric pressure, of which the limits were 751 mm. and 756 mm.

Whilst the attack measured was very much smaller than that due to water, the effect on the appearance presented certain resemblances.

Glass No. 1 towards the end of the six hours' boiling with hydrochloric acid developed a series of fine surface cracks with a slight tendency to flake when dry, like that experienced with the very high alkali glasses treated with water. The loss in weight recorded in the table was that after the first drying of the disc, since flaking continued to a slight extent with each successive drying.

Under the microscope a uniform etch pattern was found to exist (Fig. 9). The actual degree of etching was a little more marked than with water on glass No. 2. There was selective attack, whilst pits were also found to exist, although the depth did not exceed 0·1 mm.

Glass No. 2, although suffering much less loss in weight than No. 1, showed an increased tendency to flake after drying, whilst in the steam-oven cracks developed in patches circular in shape.

Under the microscope the etch pattern (Figs. 10 and 11) was found to be similar to that on glass No. 1, but a portion of the surface had patches which appeared both to the eye and to the touch to be smooth. Examination of the patches microscopically showed them to be covered with a fine network of lines; there were no pits, whilst the etching was slighter in extent than with glass No. 1.

Glass No. 3 did not show any cracks after removal from the acid, but developed a few very fine cracks on drying in the steam-oven. The photomicrographs (Figs. 12 and 13) show that an irregular etch pattern covering the surface had been developed, the attack, however, being very much less than with glass No. 2.

Glass No. 4 showed no signs of cracks, or, indeed, of attack of any kind. A magnification of 1000 with this glass failed to reveal anything but a few very small scratches, and with the remaining glasses of higher lime content no attack at all.

The Action of Strong Caustic Soda.

Very few points of interest were noted in the use of this particular reagent. With glass No. 1 the loss in weight was due largely to the shattering of the glass surface. Some difficulty was experienced also in carrying out the test, as the slab towards the end of the six-hour period was liable to explosive disruption. The solution after the attack contained a good deal of solid matter.

Glass No. 2 was slightly roughened as the result of the attack, but there was very little evidence of such attack on glass No. 3, and the attack in all cases appeared to remove and dissolve the surface of the glass uniformly, without having the penetrating effect of water.

None of the glasses after treatment with strong caustic soda showed an etch pattern, even when magnified 1000 times. What was apparent, however, was a very thin, bluish film on the surface, which could not be washed or rubbed off.

An interesting phenomenon was discovered with glass No. 1 when magnified 600 times. The disc had been suspended in the liquid by means of a piece of string. The photomicrograph (Fig. 14) shows that where the string had been in contact with the glass, a cell-like structure on the surface had been developed.

The Action of Sodium Carbonate Solution.

The loss in weight caused by the action of sodium carbonate was in the earlier glasses very pronounced. Glass No. 1 was very difficult to deal with, and although practically free from strain, five successive discs cracked explosively during the course of boiling. At the end of the test the solution contained flakes, whilst in some cases particles of glass were detached from the disc, causing the loss recorded to be probably a little high.

It will be noted in the table which follows that, after the first three glasses, the extent of corrosion reaches a value which only diminishes comparatively slowly, as is also the case with the effect of strong caustic alkali. The appearance of the glass after the attack is likewise parallel with the extent of chemical attack. Glass No. 2 had a very rough surface, and the roughening was shown with all glasses up to No. 9, but in a steadily diminishing degree. Nos. 10 and 11 were only slightly marked. Nos. 16 and 17, however, were slightly roughened. In no case did examination under the microscope lead to a discovery of any particular feature of the attack.

General Discussion of Results.

The table below summarises the effect of the four reagents used on the series of glasses. The losses in weight are expressed in terms of milligrams per square decimetre of surface. In the case of the action of water, the total amount of alkali liberated is also stated.

EFFECT OF DIFFERENT REAGENTS ON LIME-SODA GLASSES.

Losses in Weight Recorded in Terms of mg. per 100 *sq. cm.*

	Reagent : Boiling water.				
Glass.	Loss in wt.	Alkali as Na_2O.	2N-NaOH. Loss in wt.	2N-Na_2CO_3. Loss in wt.	20·24% HCl. Loss in wt.
1	24,000·0	6587·5	65·2	4618·5	158·4
2	335·4	185·4	61·1	234·0	71·4
3	157·9	111·8	60·6	83·8	18·0
4	20·9	18·4	58·8	45·5	10·2
5	10·5	10·1	56·0	35·5	6·2
6	2·5	2·5	53·6	32·3	4·6
7	1·9	1·75	51·2	30·3	3·5
8	1·4	1·25	49·4	27·8	2·5
9	0·62	0·56	46·9	26·7	1·5
10	0·57	0·53	44·6	26·0	1·0
11	0·53	0·49	42·1	25·1	0·85
16	0·70	0·60	46·3	32·7	1·7
17	0·60	0·50	49·8	25·0	1·1

It will be noted that in all cases the extent of attack of the reagent falls off very greatly as soon as quite a small proportion of lime is introduced into the glass. Making all allowance for the fact that the water and hydrochloric acid were allowed to act for six compared with three in the case of the alkaline solutions, it seems somewhat remarkable at first sight that far away the most corrosive agent in the case of the first three glasses is water, whilst the effect of strong caustic alkali is least of all the reagents.

It appears to be clear, however, not only from the results now reported, but also from previous investigations, both our own and those of other investigators, that the first step in the corrosion of a glass by water or an aqueous solution is a penetration by water of the glass surface, leading in the second place to a hydration of the glass. It has been shown that at high temperature and pressure a glass may be converted into a gelatinous hydrate, and what occurs under such conditions of temperature and pressure most probably occurs to a modified or proportionate extent at lower temperatures and pressures. If we can imagine, for example, in the case of the first two glasses that there is competition between the substance of the glass and the reagent in solution for the water, then we may have some suggestion for the results which we have to record. It is well known that sodium silicate has considerable attractive power for water. So also have caustic soda, hydrochloric acid, and sodium carbonate. If we regard hydration as the first step in the attack on a glass, we could understand that with caustic soda, which itself has a powerful attraction for water, and is itself in solution probably strongly hydrated, there would be a smaller proportion of water free to cause attack on the sodium silicate. A similar explanation would apply to the case of sodium carbonate and of hydrochloric acid. Further, we should have an explanation of the reason why sodium carbonate has on the first three glasses a more corrosive action than has strong caustic soda. As the proportion of lime in the glasses increases, we have present, undoubtedly, calcium silicate, which is stable in character and does not become hydrated. The attack on the glass, therefore, should gradually assume more of a chemical character in this case than in the earlier glasses, and the effect of initial hydration be of much less importance.

We have previously found in commercial glasses used for chemical purposes that attack by sodium carbonate was greater than that by strong caustic soda. For example, we found:—

	Attack by	
Glass designation.	$2N\text{-}NaOH$ ~~$2NaOH$.~~	$2N\text{-}Na_2CO_3$ ~~$2Na_2CO_3$.~~
J	364·0	364·3
S	273·6	397·0
R	289·1	422·5
H	470·3	600·7

The above figures refer to the losses per sq. dcm. sustained by each glass when treated for three consecutive periods at 100°. All these glasses were lime-soda glasses.* In all of them, however, the relative proportions of soda and lime are such as also exist in glasses Nos. 6 and 7, on which the attack by sodium carbonate has fallen below that of the caustic soda. We still, therefore, have to discover the reason for the more excessive attack of the sodium carbonate on the chemical glasses mentioned.

The suggestion that the first stage in the decomposition of a glass depends on the penetration of the surface by water, followed by subsequent hydration, may also have some connection with a number of little known phenomena. That a glass surface must be regarded as being in a measure porous appears to be the case, since the cause of the reaction in a number of cases when gases come in contact with glass surfaces appears to be accounted for by the initial absorption of the gases in the surface of the glass. Recently, Twyman * states that he has found some remarkable results with ether, the refractive index of which undergoes diminution in the layer immediately adjacent to the glass vessel containing it. Now, diminution of the refractive index could occur if the liquid became converted into a vapour. If absorption takes place within the surface of the glass, that absorption or penetration would be due to molecules of ether in a condition akin to the gaseous, so that the surface layer might have a refractive index lower than the body of the liquid itself.

---

* For composition, see this Journal, Trans., 1918, 2, 219.

Summary and Conclusions.

From the examination of a series of lime-soda glasses prepared under semi-commercial conditions and tested in regard to their behaviour towards water, caustic alkali, sodium carbonate, and hydrochloric acid, we have arrived at the following conclusions:—

(1) Glasses the composition of which falls within the limits of Nos. 1 to 6 should be avoided in commercial practice; that is, glasses produced from batches varying between (*a*) sand 1000, soda-ash 590, and (*b*) sand 1000, soda-ash 441, limespar 139, are unsatisfactory.

(2) All these glasses (that is, Nos. 1 to 6) are too readily attacked by the reagents concerned, and are, moreover, hydroscopic.

(3) Gradual substitution of soda by lime in a glass batch makes a glass much more stable to all kinds of liquids with which the vessel may be filled.

(4) In the glasses which contain only a very small amount of lime, water is the most corrosive reagent, and strong caustic alkali the least corrosive.

(5) From the point of view of fairly rapid melting, and of producing a soft glass for automatic or semi-automatic machines, glasses Nos. 7 to 9 may be considered as satisfactorily durable for common use.

Department of Glass Technology,
The University, Sheffield.

---

* See *Nature*, 1919, **104**, 315.

XXII.—*The Heat Expansion of Soda-lime Glasses.*

By S. English, M.Sc., A.I.C., and W. E. S. Turner, D.Sc.

(*Read at the Sheffield Meeting, February* 19*th*, 1919.)

The amount by which a piece of glass undergoes expansion when subjected to heat is a matter of first-rate importance in practically all branches of the glass industry. In the case of lampblown apparatus, junctions are not easy to make if the two glasses concerned have very different rates of expansion when heated. When, as is the case in the electric lamp-making industry, the sealing, not only of glass to glass, but also of metallic wire into glass, comes into consideration, the difficulty may be still greater. In the manufacture of sheet glass strengthened by encased wire mesh, fracture may arise during its preparation, due to difference of expansion between the metal and the glass. Further, in the artistic branch of the glass industry, the flashing or casing of one glass by another, ruby or blue on flint, or opal on flint, for example, depends for its success on obtaining two glasses with rates of expansion not far removed from one another. Otherwise the finished article will be split when subjected to the slightest action of a cutting tool.

These instances may suggest that the property is of importance only in special branches of the industry. This is not so, however. It affects every branch, and particularly concerns the subject of annealing. Other things being equal, a glass which expands readily when subjected to heat is less desirable than one with low expansion, since the effect of a sudden chill as a result of draughts in the lehr will most readily affect those glasses which expand most, and therefore also contract most for a given change of temperature. In the annealing of bottles, cracking not infrequently takes place at the bottom, the place liable to become chilled. We have already shown that the annealing temperature required to obtain lime glass with a high soda content free from strain is comparatively low, and this is a great advantage. On the other hand, such a glass expands and contracts more than one containing high lime and low soda content, so that it is very susceptible to draughts.

In order to determine the amount by which lime-soda glasses expand or contract when heat is applied or removed, the series of glasses which has been described in a preceding paper* has been investigated.

---

* This Journal, Trans., 1919, 3, p. 222.

The most important paper on the subject of thermal expansion hitherto published is that of Schott.* It contains data for a considerable number of glasses of very varying composition. The results were not derived from Schott's own experiments, but were collected from the investigations of Regnault, Winkelmann, and others. Two methods of determination were employed in the tests recorded, namely, the Fizeau method and the dilatometric. In the latter, glass under test is in the form of a bulb and is filled with mercury, the precise expansion of which is known already.

Schott demonstrated that the state of annealing of the glass affected the result. Where the glass was in hollow form, with walls of no great thickness, the existence of strain did not produce any very great effect on the result. Thus, in a lime-soda-zinc glass of percentage composition SiO_2 67·3, Al_2O_3 2·5, CaO 7·0, ZnO 7·0, B_2O_3 2·0, Na_2O 14·0, the coefficient of cubical expansion of the annealed glass was 0·00002406, whilst of that not annealed, 0·0000244, or a difference of about 1·5 per cent. Where the glass was solid, as in a rod, want of annealing produces a condition of very considerable strain. With a silicate crown glass, a finely annealed piece had a coefficient of cubical expansion of 0·00002748, whilst a highly strained piece gave a value 0·00002895, that is, about 5 per cent. higher. This result, namely, that the strained glass has the higher expansion, is general, and has been confirmed by Wolf,† and also by ourselves in experiments carried out at temperatures up to 400°.

In our experiments we have employed the dilatometric method with mercury, using special care with those glasses which underwent devitrification in the flame that no small air bubbles were entrapped. The glass tubing from which the cylindrical bulbs were made showed only very slight strain, and this was neglected. The capacity of the bulbs was such as to contain, in different experiments, between 150 and 300 grams of mercury. As in the results recorded by Schott, the temperature interval was within the range 0—100°. Each result recorded below is the mean of at least two independent experiments with different samples of glass.

The following table records the expansions in terms of the coefficient of linear expansion.‡

---

* Schott, "Vortrag in Verein zur Beford. d. Gewerbfleisses," 1892, p. 161.

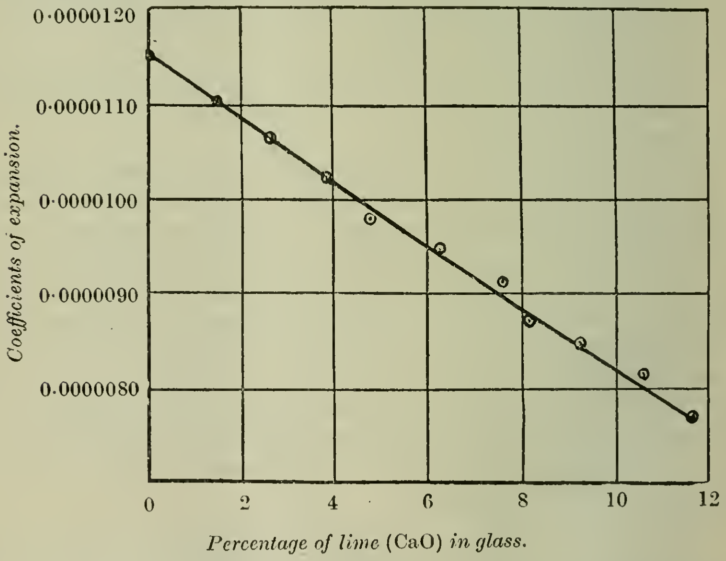
† *Sprechsaal*, 1911, **44**, 627, "Ein Beitrag zur Kenntnis des Ausdehnungs-Koeffizienten von Gläsem."

‡ The fraction of a foot by which each foot in length becomes increased when the temperature is raised 1°.

	Approx. mol. composition.			Coeff. of linear expansion.	Temp. range.
1	$6SiO_2$	$2{\cdot}0Na_2O$		0·000001153	25·0—90·0°
2	$6SiO_2$	$1{\cdot}9Na_2O$	$0{\cdot}1CaO$	0·000001106	25·3—89·8
3	$6SiO_2$	$1{\cdot}8Na_2O$	$0{\cdot}2CaO$	0·000001065	25·1—89·1
4	$6SiO_2$	$1{\cdot}7Na_2O$	$0{\cdot}3CaO$	0·000001021	25·3—89·8
5	$6SiO_2$	$1{\cdot}6Na_2O$	$0{\cdot}4CaO$	0·000000988	25·1—90·0
6	$6SiO_2$	$1{\cdot}5Na_2O$	$0{\cdot}5CaO$	0·000000947	24·6—90·6
7	$6SiO_2$	$1{\cdot}4Na_2O$	$0{\cdot}6CaO$	0·000000911	25·0—90·0
8	$6SiO_2$	$1{\cdot}3Na_2O$	$0{\cdot}7CaO$	0·000000870	25·0—90·0
9	$6SiO_2$	$1{\cdot}2Na_2O$	$0{\cdot}8CaO$	0·000000844	25·0—89·9
10	$6SiO_2$	$1{\cdot}1Na_2O$	$0{\cdot}9CaO$	0·000000810	25·0—90·0
11	$6SiO_2$	$1{\cdot}0Na_2O$	$1{\cdot}0CaO$	0·000000769	24·0—90·6
16	$3{\cdot}94SiO_2$	$0{\cdot}81Na_2O$	$1{\cdot}18CaO$	0·000000882	25·0—89·5
17	$4{\cdot}68SiO_2$	$0{\cdot}75Na_2O$	$1{\cdot}25CaO$	0·000000801	25·0—90·0

The results for the glasses 1—11, which are all based on one type, are also recorded in graphical form, with coefficients of expansion plotted against the percentage of lime (CaO) contained in the glass. It will be noted that the resulting curve is practically a straight line, so that the relation between composition and coefficient of expansion in a series of similar glasses follows a very simple law. When it is borne in mind that an error of 0·1 per cent. in the analytical determination of the composition of the glass would affect the curve distinctly, and when, moreover, it is

Relation between coefficient of expansion and composition of lime-soda glasses



remembered that it is almost impossible to ensure the preparation of a non-crystalline substance like glass of a definite molecular composition, it appears quite warrantable to assume that the true relationship of composition to the coefficient of expansion is represented accurately by a straight line.

Schott, indeed, in a further paper,* arrived at the conclusion that it was possible to attribute to each 1 per cent. of each oxide entering into the composition of the glass a definite proportion of the total coefficient of cubical expansion of the glass. Thus, for each 1 per cent. of silica, the contribution would be 0·00000008; for soda (Na_2O) 0·000001; for lime (CaO) 0·0000005. If, therefore, the percentages of silica, soda, and lime respectively in the glass be represented as x, y, and z, the cubical expansion of the glass will be $0{\cdot}00000008x + 0{\cdot}000001y + 0{\cdot}0000005z$.

We have found, however, that quite a number of deviations from the rule occur. One might expect to get good agreement between members of a series of similar glasses, such as the glasses 1—11 above, and we have tested the rule with our own series, with the following results. For simplicity we have omitted all ciphers and given only the significant figures. The linear coefficients are quoted.

Test of Schott's Rule for Coefficient of Expansion.

	Linear coefficient of expansion.		
Glass No.	Calculated by Schott's rule.	Experiment.	Difference.
1	1053	1153	−100
2	1036	1106	−70
3	1013	1065	−52
4	993	1021	−28
5	981	988	−7
6	958	947	+11
7	916	911	+5
8	886	870	+16
9	862	844	+18
10	850	810	+40
11	822	769	+53
16	923	881	+42
17	789	801	+12

The differences will be seen to be very considerable and to make it evident that, whether a general rule can be prescribed or not, Schott's factors, at any rate, cannot be considered as having any wide validity. We ourselves have calculated a new set of factors for this series of glasses which lead to close agreement between the calculated and experimental values. For the present we refrain from quoting them until we can test them more widely.

---

* *Ann. Physik*, 1894, **51**, 735.

Conclusions.

Returning now to the general subject, we conclude:—

(1) That in a series of lime-soda glasses of generally similar type, the variation of the composition and the coefficient of expansion are related to one another in a simple additive manner.

(2) In similar lime-soda glasses, those with highest soda content have the greatest rate of expansion, reduction of expansion occurring with successive increase in the lime content and diminution of soda.

(3) Schott's factors for the calculation of coefficients of expansion contain considerable errors.

Department of Glass Technology,
The University, Sheffield.

XXIII.—*The Manufacture of Table Ware in Tank Furnaces.*

By R. L. Frink.

(*Read at the Leeds Meeting, October* 19*th*, 1919.)

I present this paper at the invitation of one of your members whom I consider to be sufficiently familiar with your methods and practice, as also with the methods and practice of our American industries, to be competent to judge as to whether or not it may fall within my province and capabilities to submit to experienced gentlemen anything that may be interesting and new.

The title was suggested as a result of a discussion concerning the efficacy and efficiency of the pot furnace in comparison with the tank furnace for the making and melting of flint, table ware, or crystal glass.

Possibly it would be well for me to define here what we, in America, consider to be flint glass. Flint glass with us means, in general, anything which is clear or crystal-like, and usually takes no account of composition. However, this paper, and I trust its subsequent discussion by your members, regards as flint glass one having a composition between the limits silica 78 per cent., calcium oxide 6 per cent., and sodium and potassium oxides 16 per cent., and silica 62 per cent., lead oxide 26 per cent., potassium and sodium 12 per cent.

Therefore you will observe that my presentation of the use of a tank furnace for the manufacture of table ware or flint glass takes in a considerable territory, and I trust that you will recognise that my attempt to present the conditions governing the design and operation of tank furnaces suitable for producing a glass of first quality must be subject to certain qualifications, since one can here deal only with the general problem and not with all the details met with in actual practice.

I am not saying this as wishing to suggest an *alibi* for any shortcomings which may be found in my account of this subject, for I am confident there will be many, but rather for the purpose of stimulating discussion and to learn from you those practical difficulties which you believe to exist by pointing out to me wherein we are at fault, or do not possess the knowledge and technique whereby we cannot produce in a tank furnace all or more glasses than it is possible to create in the best type of pot furnace of which you can conceive.

Now, having declared myself, permit me to present some of the problems which are encountered and successfully solved in connection with the production in a tank furnace of the flint glass of composition specified above. Therefore, let us first divide flint glass into two classes, namely, lead flints and lime flints, and, secondly, subdivide these two classes as follows:—

Lead Flints.—Optical glass, bulb glass, and cut-glass blanks. Table ware.

Lime Flints.—Bulb glass, blown stem ware, pressed ware, blown ware (as chemical ware, vases, chimneys), and pressed cutting blanks; also blown pressed ware, whether made upon the machine or by the hand method.

Until about five or six years ago it was considered as impracticable to melt lead glass in a tank furnace, because of the reducing action which occurred, due to imperfect combustion of the gas or fuel entering the furnace. It has since been found and demonstrated that it is not at all impossible, but that with proper furnace construction and operation it is possible to melt perfectly these glasses without any reduction of the lead or other metallic oxides which enter into the batch composition.

Furnace design, however, is comparatively simple when considered in relation to the difficulties encountered in developing the knowledge and education of the operators, whereby they can produce at all times these combustion conditions and at the same time maintain a temperature sufficient to melt the batch constituents and produce a homogeneous and crystal metal. Immediately the question arises in one's mind as to why any such difficulties should be presented, and the answer is found substantially in the fact that probably 90 per cent. of our tank furnace operators have been drawn from the ranks of old glass makers whose experience has been confined entirely to pot furnace operation. As we all know, the operation of the old pot furnace meant the production within the furnace proper of an atmosphere which is primarily and essentially a reducing one. In other words, within such a furnace the temperature results from an evolution of heat produced by the incomplete combustion of the fuel introduced.

If, therefore, one has been trained to produce a given temperature, by regulation of fuel and air supply, which calls for the creation of a long, luminous flame, it must immediately become obvious that there is no part of that flame but has a reducing effect upon the material with which it comes in contact. This is made evident by the colour of the pots which protect the glass from this reducing action. In a tank furnace, such reducing action is detrimental in proportion to the period of time during which such flame is in contact with the batch or glass-making constituents.

Consequently, the man who is delegated to assume the responsibility of operating a tank furnace, of the design of which he has had no previous knowledge, naturally will apply his past experience and practice, and will consider that in order to obtain the production of a required quantity of glass at the working end he must of necessity obtain a *volume* of fire analogous to that which he would consider necessary to obtain a required melting capacity within a pot furnace, with the result that he has to a considerable degree reduced his lead oxide, causing a dark or cloudy glass unsuitable and unsatisfactory for commercial purposes.

In order to operate a tank furnace to produce a lead glass, it is absolutely imperative from the very beginning that the furnace must be so designed that combustion does not occur at the surface of the melting glass, and must be so regulated that there shall at no time be produced a flame which contains any free carbon upon the melting batch.

In my classification of lead flints I have mentioned optical glass, and have done so, not because I can cite any instance of its successful accomplishment, but because I am firmly convinced that it is a possibility. In fact, I believe that with a properly designed furnace, properly operated, it is possible to produce a lead glass of a quality and homogeneity equal or superior to that produced in pots. For it is a difficult matter to produce lead glass, in pots, which will give the same index of refraction and dispersion values throughout the whole mass from the top downwards.

In a tank furnace properly designed, all the glass melted is required to mix during its travel from the melting to the refining end, and thereby produce a condition which cannot help but at least facilitate a thorough amalgamation. Further than this, if this glass is melted under tank furnace conditions there is a more rapid and immediate presentation of heat to the components of the glass or batch, which will result in increasing the rapidity of chemical combination, thereby reducing to the minimum (according to the accuracy of furnace regulation) segregation and lamination.

In addition to this, it is possible with proper furnace design to submit a greater area of batch to the effects of heat than is possible in pot practice, thereby increasing fuel efficiency.

I have only suggested the principal difficulties which confront the furnace operator in the production of lead glass, and these conditions are but primary and fundamental; there are others which must be observed in order to produce a first quality lead flint from tank furnaces.

Assuming that a furnace has been so operated as to deliver to the working end a glass which is crystal clear, free from reduced lead, blisters, stone or unmelted batch, and lamination or striæ, so good, in fact, that it can be made into a finished article by hand or mechanical processes, we are yet not beyond the pale of trouble and possible defects which will prevent the production of sound, saleable ware.

This is because, although this glass may be delivered to the melting end thoroughly melted and free from all uncombined material, it is possible that currents of gases within the furnace have created differences in temperature between the surface glass and that which underlies it, or, on the other hand, well-defined local areas of varying temperature conditions are set up, resulting in variation of density from point to point and leading ultimately tc apparent lamination or striæ in articles made from it.

This last condition is particularly evident in the manufacture of electric light bulbs, wherein even the smallest string or cord produced by the above-mentioned conditions becomes very pronounced and objectionable.

Variation in the direction of the wind, the atmospheric conditions, or the relation between the effective stack draught upon the furnace and the volume of gases introduced therein may all be responsible for the production of eddy currents in the furnace and of striæ in the glass.

There is, in my judgment, another condition which must be observed with serious consideration in order that flint glass may be successfully produced in tank furnaces, namely, that of a thorough and complete chemical combination of all the batch constituents of a lead glass, and this in turn depends on the facility with which they can be subjected to uniform heating at a sufficiently high temperature. Failing uniform heating, lamination and striæ will result. I have found that one successful way of accomplishing satisfactory glass melting is to fill into the furnace the batch and cullet in small portions and distribute them over as great an area as possible, never permitting large piles or lumps to accumulate, since the interior of such lumps may attain a temperature exceeding 1100° before its exterior is under active and substantially uniform chemical action.

What I have said regarding furnace operation in the production of lead flint glass is likewise true in its essentials in making a first quality of lime "flint," with a few exceptions.

Let me direct your attention to the temperature and fire requirements in melting a glass, the composition of which, on the one hand, would be approximately silica 78 per cent., calcium and magnesium oxides 6 per cent., sodium oxide 14·5 per cent., iron oxide and alumina 1·5 per cent., and, on the other, silica 72 per cent., calcium and magnesium oxides 6 per cent., sodium oxide 21 per cent., and iron oxide and alumina 1 per cent., or one which contained silica 72·5 per cent., calcium and magnesium oxides 12·5 per cent., sodium oxide 13·5 per cent., iron oxide and alumina 1·5 per cent. These embrace the range of compositions I have found to exist in the so-called lime flint glasses produced in America. As you know, the second composition, having a high soda content, is that of a glass which melts at a comparatively low temperature, and although it is susceptible to stratification in the batch materials themselves, the glass itself is also very susceptible to severe lamination and striæ in the finished state. This is particularly true when the temperature distribution at the melting end is variable and insufficient to create rapid and effective chemical combination; for as the soda is increased relatively to the lime, magnesia, alumina, and silica, the time required for fusion is shortened. Consequently, it is necessary that the immediate surface temperature of the batch should be maintained uniform throughout.

It is possible that this statement may be called in question, particularly by those whose experience is based on pot furnace practice. However, I will permit the statement to stand, without going into further detail, than to say that my experience conclusively proves that where soda or potash or a combination of the two exists in excess of 17 per cent., it is very difficult to maintain glass in a state of sufficient homogeneity for commercial articles to be produced sufficiently free from striæ and laminations and capable of ready annealing.

It is, no doubt, already obvious that a glass of the above composition presents some special difficulties when made in a tank furnace, and this is particularly true when such furnace is subject to the control of an operator having had only pot furnace experience. The difficulty is due, not only to irregularity of temperature distribution, but also to the existence of a reducing atmosphere, causing variation in the colour of the glass from pink to green. This is particularly true where manganese is used as a decoloriser; but it is also in some degree true where selenium is used as the basic constituent of the decoloriser, although there are decolorisers used which reduce this effect to the minimum.

What has been said in this respect regarding a high soda glass is to a great extent true of all the glasses throughout the range of compositions stated, although, of course, as the soda content decreases and the temperature of the furnace increases, reducing action and its effect upon colour diminishes.

So far, I have presented the difficulties which one encounters in making crystal or flint glass, considering only the furnace and its operation as related to glass composition, and have purposely left for a last consideration what is probably the most important factor, namely, fuel supply.

In Great Britain, I understand, it is necessary to rely entirely on coal as a fuel, and therefore on producer gas.

Now, in the making of flint or crystal glass in tank furnaces using producer gas, the factor of great importance is but too little recognised. It does not reside in the furnace, but in the gas generator; for unless gas can be delivered to the furnace uniform in volume and heat value it is impossible to attain a sufficient temperature to avoid the above-mentioned difficulties. This means that two conditions must be under control and should be automatically regulated.

First, an ample and uniform quantity of gas should be provided of moderate heat value. In fact, I would prefer a constant volume of 140 B.T.U. gas to a varying volume of 160 to 170 B.T.U. It will be recognised that if valves and dampers are set to give proper combustion and temperature of either, or even of a mean of the two gases, then during the period of poor gas imperfect melting occurs, and during the flow of rich gas colour is destroyed.

Secondly, either an automatic gas regulator should be applied, together with means for determining accurately chimney draught control, or conscientious and careful observation and attention should be given to the adjustment of the chimney damper, air, and gas valves.

In conclusion, let me summarise the conditions which in my opinion are essential to successful glass melting. They are:—

(1) Constant and uniform delivery of gas to furnace.

(2) A supply of air at a suitable temperature to effect complete combustion.

(3) The removal of gases of combustion as rapidly as produced within the furnace.

(4) Suitable furnace construction whereby unconsumed gases will not come into contact with melting batch.

(5) Proper introduction and distribution of batch within the furnace.

(6) Creation of temperature sufficient to effect a rapid and complete chemical combination of batch constituents.

(7) No furnace should deliver less than 9 lb. of glass per sq. ft. of melting area per hour to ensure glass of first quality in colour and homogeneity, and freedom from seed and stones.

LANCASTER, OHIO,
U.S.A.

DISCUSSION.

Mr. S. N. **JENKINSON** inquired whether or not the author drew any distinction between optician and optical glass.

Mr. **FRINK**, in reply, said that in optical glass he included glass for optical instruments, not merely glass for spectacles. He had a camera with a lens which he had made himself in a tank furnace.

Mr. W. J. **REES** desired information on the use of selenium as a decoloriser in an ordinary batch in which oxidising agents were used.

Mr. **FRINK** quoted the following typical composition, and said anything but soda-ash batches with very little nitre were seldom used:—Sand, 1000 lb.; soda ash, 380 lb.; soda nitre, 40 lb.; limespar, 210 lb.; selenium, 0·3 ounce. With lead batches the conditions were different.

Mr. J. H. **DAVIDSON** inquired as to the purity of the materials used.

Mr. **FRINK** gave the following figures:—Sand, SiO_2, 99·4 to 99·8 per cent.; Fe_2O_3, 0·08 per cent. There were only two or three sands in the United States that could be drawn upon. Usually the composition for double-washed sands was:—SiO_2, 98·75; Fe_2O_3, 1·2 to 0·08; Al_2O_3, 0·2 to 0·6. For limestones:—$CaCO_3$, 96·0; Fe_2O_3, 0·80 to 0·25 (extremes), or 0·08 for average good samples. As to decolorising, if the glass was melted at the rate of 10½ lb. per sq. ft. per hour, 0·8 per cent. Fe_2O_3 in the sand could be decolorised.

Mr. Rees asked what was the present position in America with regard to the use of alumina in glass batches.

Mr. Frink said the question had resuscitated an old child of his. 2·8 to 3 per cent. of alumina gave good results. The tensile strength was increased and devitrification was decreased. The lime could be increased and soda decreased, leading to a greater heat endurance. However, alumina was not generally used.

Mr. C. J. Peddle also dealt with the purity of materials, and referred specially to optical glass. He also dealt with the question of the economy of working.

Mr. Frink replied that their red lead contained about 1¼ per cent. of free lead. As regards economy of working, in one case it was 58 per cent., that is, 58 lb. of coal were consumed for 100 lb. of glass delivered at the front of the furnace. A good average practice yielded 68 to 72 per cent., but 110 to 114 per cent. was frequently met with.

Mr. T. W. Ferry inquired as to the continuous working of lead glass.

Mr. Frink said that it was used in day tanks having a capacity of some 2½ tons.

XXIV.—*A Proposed Standard Formula for a Glass for Lamp-workers.*

By F. W. Branson, F.I.C., and F. H. Branson, A.I.C.

(*Read at the Sheffield Meeting, November* 19*th*, 1919.)

On the occasion of the annual meeting of the British Laboratory Ware Association, Ltd., in January last, a request was made to one of us to undertake an investigation which would secure a much needed and ample supply of glass tubing of uniformly good quality of British manufacture for lamp-workers. This subject was brought before the committee on the standardisation of laboratory glassware of the Society of Chemical Industry, but as its terms of reference did not include standardisation of glass tubing, no action was taken. A research committee of the Society of Glass Technology has been appointed, however, the scope of which includes lampworking glass as well as other types.

In two communications to the Society of Chemical Industry * will be found, quoted by one of us, the composition of the principal German glasses in use in this country in 1914. From the analytical data obtained we proceeded to melt experimental batches on a small scale, and finally on a manufacturing scale, using for the zinc–borosilicate glass sodium nitrate as an oxidiser and felspar as a source of alumina. A similar procedure was adopted for the new glass referred to later as Batch No. 6, which is mentioned in a minute of the meeting of the members of the British Laboratory Ware Association held in London on November 11th, 1919, as follows:—"The tubing has been thoroughly tested and proved most satisfactory."

A consensus of opinion undoubtedly exists in favour of the standardisation of glass tubings for lamp-workers, and we have made the basis of our work a pre-war imported tubing, which was found satisfactory over a long period for high-class lamp-blown work. This glass, made into a gas analysis apparatus for a Government department in February, 1913, was found to retain its good working qualities after a period of five years. The composition of the glass, taken from a portion of this apparatus, is:—

SiO_2	69·64
Al_2O_3	3·02
Fe_2O_3	0·06
MnO	0·18
CaO	6·40
MgO	0·37
K_2O	6·98
Na_2O	13·36
Total	100·01

Comprehensive tests were made for other elements, with negative results, complete absence of arsenic and antimony being proved.

In order to secure from this analytical result a formula for a glass suitable for lamp-blown work, a series of meltings was made approximating to the following batch mixture, in all of which the alumina content was maintained such as to give in the resulting glass a proportion of 4 per cent. of Al_2O_3. These experiments led to a formula which may be regarded as a basic one, capable of easy modification with regard to altered proportions of any one or more of its constituents.

---

* *Vide J. Soc. Chem. Ind.*, 1915, **34**, and 1918, **37**, 337T.

No. 6 Batch Mixture for the New Glass.

Sand	1104
Potash felspar	400
Limespar	222
Potassium nitrate	213
Soda ash (95 per cent.)	410
MnO_2 (87 per cent.)	3

The above mixture costs less than one penny per pound for materials.

The experiments included the melting of seven batches (four in gas, two in coke, and one in electric furnaces), which resulted in the production of a range of glass from soft to hard, from which glass tubing was drawn and tested. The proportions above-mentioned were found to produce a moderately hard glass suitable for many purposes for which a superior tubing is required, for example, the making of plugs, stopcocks, and the blowing of bulbs, which may be re-blown many times without devitrification. The tubing joins on to the best British made glasses, including the resistant varieties, and is quite suitable for the repair of pre-war imported chemical glassware.

The new glass conforms to the following specification:—(1) Freedom from appreciable colour. (2) Absence of tendency to devitrification. (3) Facility of fusion on to glasses of various degrees of hardness and composition. (4) Does not appreciably darken in the blowpipe flame. (5) A suitable viscosity, in other words, good working properties for lamp-blown work.

As the absence of an appreciable amount of colour in the glass is important, the constituents should be practically free from iron and other injurious impurities.

EXPERIMENTAL.

Percentage composition of Ingredients used for Batch Mixture.

Potash felspar (Cornish)	SiO_2	66·6
	K_2O	10·0
	Al_2O_3	20·0
	Na_2O	2·6
	CaO	0·7
	MgO	Nil.
	Fe_2O_3	0·4
		100·3
Sand (Fontainebleau) unwashed	SiO_2	99·6
	Al_2O_3	0·21
	Fe_2O_3	0·03
	Loss on ignition.	0·12
		99·96

Percentage Composition of Ingredients used for Batch Mixture.

Limespar	$CaCO_3$	98·89
	SiO_2	0·61
	Fe_2O_3	0·05
	Al_2O_3	0·08
	MgO	0·31
		99·94

Soda ash. Heavy, in very fine powder sifted. Moisture 5 per cent., $NaCl$, 1·025, Na_2SO_4, 0·17.

Potassium nitrate. Practically pure, contained a trace of iron (0·002 per cent.).

Furnace Methods Employed.

The fuel used in the furnace was coal gas, the air being introduced under pressure. The pots used were of Stourbridge clay, and were first heated in the gas furnace at 1000° and then vitrified at a temperature of 1350°. The amount of batch introduced into the 56-lb. pot was 31 lb. in three portions of about 10 lb. each at intervals of two hours. The temperature of the furnace was maintained at 1340° for fourteen hours; the batch fused easily, aided by the use of nitrate, causing quicker melting, which is a distinct advantage. Careful attention having been given to the mixing of the batch and to the founding, the glass plained well, and in the hands of the tube drawer drew easily. With regard to the loss of alkali during fusion and the absence of attack by glass on the pots, these were, owing to the excellent experimental conditions and the low percentage of impurities in the batch mixture, reduced to negligible quantities.

	I.	II.
SiO_2	70·35	69·67
Al_2O_3	4·06	4·06
Fe_2O_3	0·04	0·06
MgO	0·36	0·36
CaO	7·1	6·51
MnO	0·16	0·16
K_2O	6·85	7·1
Na_2O	10·66	12·05
	99·58	99·97

The glass "No. 6" was afterwards analysed, with the results indicated under I, the composition of the batch in terms of the oxides which should remain in the glass being given under II, clearly showing that very little action on the pot had taken place. The loss of alkali was small, but in a tank furnace on a manufacturing scale an allowance for a larger loss of from 2 per cent. alkali will probably be found necessary. With good materials and a covered pot in a gas furnace and the use of nitrate practically very little manganese is required, but on a large manufacturing scale, using a tank furnace with a reducing atmosphere, the maximum quantity of MnO_2 used in our experiments (as in the batch mixture) will probably be found sufficient.

Our best thanks are due to the Department of Glass Technology, University of Sheffield, for the facilities placed at our disposal for melting on a semi-manufacturing scale three batches of the new glass, and especially to Mr. F. W. Hodkin, B.Sc., for superintending them; also to Messrs. Reynolds and Branson, Ltd., for the use of their analytical research laboratory and appliances for making experimental meltings.

14, Commercial Street,
Leeds.

XXV.—*Glass for Table Working.*

By M. W. Travers, D.Sc., F.R.S.

Many years ago a German manufacturer told the author that he made two kinds of lamp-working glasses. One variety deteriorated if kept for longer than six months before it was worked, whilst it was the writer's personal experience that the other variety, used for making the best chemical apparatus, would work well before the blowpipe, even after the apparatus had been in use for many years. He had found, moreover, from personal experience that some kinds of glass, when shipped out to India, proved quite useless, as the glass devitrified immediately it was heated. He had attributed the trouble to the absorption of moisture by the glass, but he had not, while in India, an opportunity of carrying the investigation further.

In the autumn of 1914 the author's friends, Messrs. Baird and Tatlock (London), Ltd., had supplied him with a number of samples of glass tubing, some of which, from their practical experience, had been found to be good and some bad, at least in the sense that the glass was not workable when it had been kept for some time. He made a number of analyses, and came to the conclusion that the high quality glasses contained both soda and potash,* and the low quality glasses soda alone. He advised his friends, who were proposing to manufacture table-working tube, to make a glass approximating to the formula

---

* This conclusion appears to conflict with that arrived at by Schott, *vide Jena Glass*, Hovestadt, 1902, § 133, p. 324.

SiO_2	68	K_2O	7
Al_2O_3	4	Na_2O	13
CaO	7·5		

There would naturally be present traces of iron, manganese, and magnesia.

Experimental batches were made up and melted in a small oil furnace in 1 cwt. pots. The alumina was derived from commercial alumina, china clay, or felspar, and the potash from commercial potash or from saltpetre, but the same glass was always obtained. As soon as the full-scale furnaces were completed, the production of the glass was commenced on a commercial scale, first using the felspar–potash batch, and, when potash became unobtainable, the felspar–saltpetre batch. Some thousands of tons of the glass were manufactured during the war by the author's firm (Duroglass, Ltd.) for table-working glass tubing and for such articles as petri dishes and heavy chemical ware.

The author had been well aware from the outset that there was much room for research on table-working glass, and in a paper read before the Society of Chemical Industry in July, 1918, he had directed attention to the matter in the words: "We know that a soda–lime–alumina–silica glass does not work as well before the blowpipe as a glass containing potash, whilst it also tends to devitrify, particularly if it has been in stock for some time. But what proportion of soda to potash will give the best result? Only a research conducted by the chemist, the glass manufacturer, and the practical chemist can tell us. Again, with certain proportions of potash, the glass becomes difficult to free from minute seeds." The matter was then taken up between himself and Dr. Turner, in correspondence, and further investigations on pre-war table working glasses were carried out which tended to confirm the conclusion that the best of the glasses approximated to the composition

SiO_2	67 to 69	K_2O	7 to 6
Al_2O_3	3 ,, 4	Na_2O	13 ,, 12
CaO	6 ,, 8		

The more lime the glass contained, the smaller was the alkali content.

At this stage it would have been quite safe to inform manufacturers that if they made glass approximating to such a composition it would certainly prove satisfactory to the lamp-workers. The author knew, however, from practical experience that such a glass was not an easy one to manufacture. Though a soft glass, it plained only at a high temperature, and he did not think that the production of it from direct-fired or semi-gas-fired furnaces would be likely to prove a paying proposition. It must also be remembered that the glass was an expensive one, and that a cheaper glass would be equally suitable for articles such as ampoules.

In May last the Society had appointed a committee to deal with the problem of table-working glass, and a considerable amount of information had been collected, but experimental work had been delayed pending the formation of the Research Association. He might, however, be permitted to express his own views on the subject. The problem was largely one of furnace practice, for British glass tubing too often bore evidence of the fact that the glass had not been founded at a sufficiently high temperature. He would urge manufacturers to adopt small tanks and gas-fired furnaces for the manufacture of table-working glass tubing. Most direct-fired and semi-gas-fired furnaces could be converted for gas-firing without difficulty. In this respect our manufacturers must get abreast of the times.

With regard to future research, they must get away from tradition. The addition of alumina to glass had originally been accidental, and the tendency had been to reproduce from alumina-free sands, by the addition of aluminous minerals, glasses which had been accidentally discovered through the use of alumina-containing sands. A short time ago Prof. J. N. Collie, F.R.S., of University College, London, had given the author a piece of tubing which he (Prof. Collie) had had in his possession for about twenty years, and which he considered to be the best table-working glass he had ever come across. When this glass was examined by Dr. Turner it was found to have the composition

SiO_2	61·26	K_2O	3·98
Al_2O_3	7·92	Na_2O	13·08
CaO	9·25	Sb_2O_3	3·45

The high percentage of alumina is remarkable, and it is noteworthy that a glass approaching such a composition could be made with felspar without the addition of potash in any other form. In view of the relative cost of potash from felspar and of potash in the form of carbonate or nitrate, this is of great importance. This glass would seal to ordinary table-working glasses, forming a perfect junction.

The problem at the moment is to determine how high the percentage of alumina could be raised, so as to avoid the necessity of adding potash to the batch in any form other than felspar. The investigation of the extent to which the alkalis, and particularly the potash, could be replaced by lime was of almost equal importance. This would involve the melting of a considerable number of batches on a small scale and the testing of the products by chemical and physical methods which were under consideration, and, finally, the carrying out of full-scale experiments to ascertain whether the manufacture of the glasses presented particular difficulties.

Beacon Hall, Priory Gardens,
Highgate, London, N. 6.

XXVI.—*The Polariscope and its Application to the Glass Industry.*[*]

By G. V. Wilson, B.Sc.

The use of a polariscope for detecting strained areas in glass due mainly to faulty annealing is not by any means an innovation, but is simply another case of a well-known scientific principle which has come to the fore as a direct result of the war. As far back as the middle of last century the use of such an instrument was suggested as a means whereby either the manufacturer or the housewife could tell the quality of glass articles of everyday use. In the following account a well-known type of polariscope is described, together with a few extra fittings which render it useful as a glass works instrument.

In essence, a polariscope consists of two parts only, a *polariser* and an *analyser*, and it may be as well to state that any type of polarising device can be used as an analyser and *vice versa*, though for the purpose of an analyser some types are much more efficient.

---

[*] The two papers by Mr. English and by Mr. Wilson were submitted for publication almost simultaneously. They have some features in common, but in other respects are complementary. Neither claims novelty. In Germany such apparatus has been somewhat better known than in this country, although even fifty years ago such an instrument was used for a period in the works of Messrs. Osler of Birmingham, and optical glass makers and workers naturally have long employed it. In America at the present time many works also have strain "viewers." Whilst the physical principles of the apparatus are commonplace knowledge, it is most desirable that glass manufacturers generally shall recognise there is a means of eliminating bad annealing. Herein lies the value of the two papers. It may be remarked, in conclusion, that the method does not apply to dark coloured glasses owing to the difficulty which the light has in penetrating them.—W.E.S.T.

In the instrument under consideration, the polariser, *A* (Fig. 1), consists of a pile of clean, thin glass plates, ten or twelve in number, the bottom one being blackened on the back, or preferably a sheet of dark pot metal or heavily flashed glass can be used. This pile is set perfectly flat, so that light from any source, for example, strong daylight, can fall on it and so be reflected.

Part of this reflected light is polarised, and the amount is greatest when the angle of incidence, i, is such that its tangent equals the refractive index of the glass used for the pile. After reflection, the light leaves the glass plate at an angle, i', equal to the angle of incidence, and is now a beam of so-called plane polarised light. If, now, this plane polarised beam be examined with an analyser, *B*, in this case a Nicol prism, we find that on rotating the Nicol the amount of light transmitted to the eye varies from a maximum to absolute darkness. When this latter condition is reached, the polariscope is correctly set for the examination of glass for strain. If, now, we place a piece of glass ware, say a flask, with its long axis, *p*, at 45° to the edges of the polarising plates, in the path of the beam, *C*, and examine it through the analyser, one of two things will be noticed.

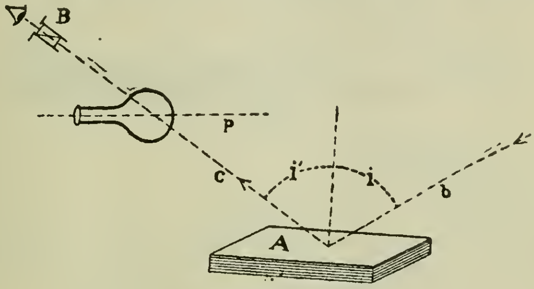


FIG. 1.

(1) The field of the instrument will remain uniformly dark and only the outline of the object will be seen.
(2) Certain areas of the flask will be illuminated by parallel bands of light.

In the first case the object is not strained, and in the second strain exists, the illuminated bands indicating the position of strain, whilst the intensity and colour of the transmitted light give some idea as to the amount present. Thus, faint light grey bands indicate that the amount is small and for many purposes negligible, but if the bands are coloured, then the glass needs re-annealing.

By inserting a plate of selenite of such a thickness as to give the sensitive violet tint* in the proper position under the analyser and above the object, the instrument is made much more delicate, and comparatively slight strains can be recognised owing to the differences in colour being accentuated.

---

* First used by Biot in 1813.

The following diagram, Fig. 2, gives an idea of an instrument devised on these lines for the use of glass manufacturers.

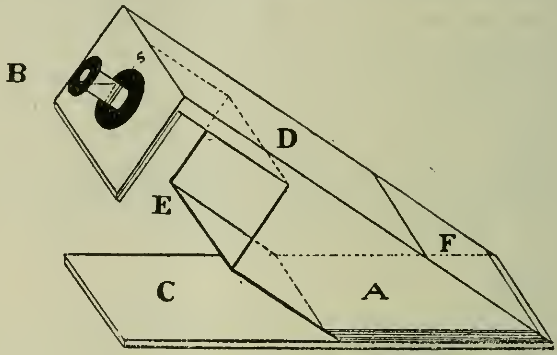


FIG. 2.

A. Pile of plates (Polariser).
B. Nicol prism analyser with selenite plate.
C. Wooden base.
D. Square wooden tube, blackened inside, to exclude extraneous light.
E. Space for article under examination.
F. Window of finely-ground glass to diffuse incident light.

H.M. GEOLOGICAL SURVEY OFFICE,
33, GEORGE SQUARE, EDINBURGH.

XXVII.—*A Simple Apparatus for the Detection of Strain in Glass.*

By S. ENGLISH, M.Sc.

IN a recent lecture at Stourbridge, Dr. Turner directed attention once more to the desirability of examining all articles, especially heavy blanks, in order to see that they were well annealed before being sent forward to the cutting shop, as it is not an infrequent experience that a glass dish or other article is shattered on the wheel after a good deal of time has been spent in its partial decoration.

Dr. Turner requested me, therefore, to attempt to devise an instrument in which polarised light would be utilised for the detection of bad annealing, and so to construct it that it would be very simple in use and easy to make, capable of being put together in the carpenter's shop attached to any of the works.

I have endeavoured to follow out these lines in the two types of instrument, details for the construction of which are given below.

A wooden box is built up to the dimensions given in Fig. 1

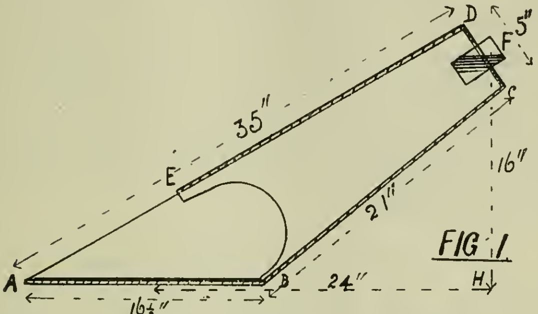


FIG 1.

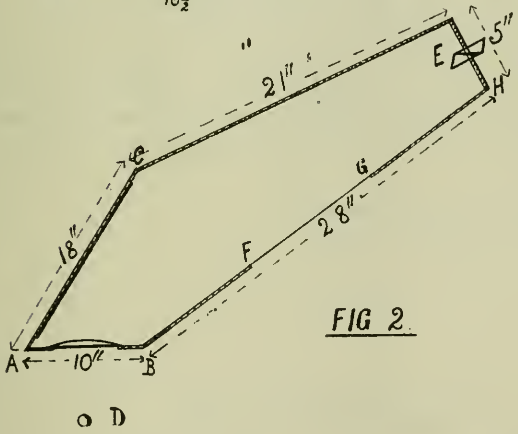


FIG 2.

The base is 16½ inches long, about 8 or 9 inches wide, and preferably ⅜-inch thick. One side *ABCD*, the small end *CD*, and the lower part *BC* are built up completely, while the top piece is only carried as far down as *E*, 12 inches from *A*, and the remaining side is cut away as shown by the curved line joining *E* and *B*. A hole is cut in the end *DC* in such a position that its vertical height above *H* is two-thirds of the distance from *H* to the middle of *AB*. The whole of this box is painted dull black on the inside.

A piece of plate glass (16 by 8 or 9 inches), or preferably several layers of sheet glass, are laid on the base piece AB. In the hole in the small end is placed a tin box, open at each end, containing about 24 thin sheets of glass (for example, microscope slides 2 by 1 inches) so fixed that when the box is in position the slides are horizontal. This apparatus works well with bright skylight.

Another form of apparatus, using an artificial source of light, may be constructed as shown in Fig. 2, which represents a plan view of it. It is important that the distance BC should be one and a-half times AB. A distance FG of about 12 inches is left open in the side BH. A 5-inch circular hole is cut in the middle of the side AB, and a lens of 6 inches diameter is fitted on the inside as shown. The several sheets of glass stand vertically along the side AC. The source of light, D, is placed in such a position that the light passing through the lens is reflected from the glass plates and focussed on the eyepiece E. If a Nicol prism be used as eyepiece in this form of apparatus instead of the box of glass slides, a rather better effect is obtained.

Operation of the Instrument.

On looking through the eyepiece at the sheet of glass, it should appear practically uniformly dark, and if on holding a piece of glassware in the path of the light passing to the eyepiece bright patches of light appear, such patches of light indicate that the glass is strained. If no light reappears, or the light seen is comparatively faint, then it may be taken that the glass is well annealed.

Department of Glass Technology,
The University, Sheffield.

XXVIII.—*The Influence of Lime on the Value of Young's Modulus of Elasticity for the Lime-soda Glasses.*

By J. R. Clarke, M.Sc., and W. E. S. Turner, D.Sc.

In selecting a glass for any particular purpose, it is usually found necessary to compromise between a number of different properties. The factors to be taken into account are quite numerous and have frequently to be considered from the point of view of the possibilities of manufacture, as well as of use. We have already dealt in previous papers with such properties of the lime-soda glasses as the upper annealing temperature and the coefficient of expansion, whilst others are under investigation. Amongst these, the properties which have to do with the mechanical strength of a glass cannot be neglected. Remembering that Young's modulus of elasticity is defined as the ratio of the stress applied to the strain which the object undergoes under that stress, it will be recognised that the determination of its value is important, since the amount of strain which can be developed in a glass without fracture is related to the elasticity. Measurements have therefore been made of this property with the series of glasses described in a former paper.*

The method adopted was to observe the bending of a glass rod supported at its two ends and weighted at the middle. In this method it is necessary, in order that a precise result shall be obtained, that the rod shall be as nearly perfectly cylindrical as possible, that it shall be of uniform diameter throughout the length, and, finally, that it shall be homogeneous and free from bubbles. In the glasses under test, since the meltings were not made on a very large scale, it was difficult to fulfil these conditions precisely. Nevertheless, the rods were of such a character that in a length of 20 cm. the diameter did not vary more than 1 per cent. throughout the length. This limit of error would make possible an error of about 4 per cent. in the final value of the elasticity constant, and whilst this limit is quite legitimate, it was not considered necessary to attempt either to make very precise measurements of the extent of the bending or to apply slight corrections for the error introduced into the formula by which the results are evaluated by assuming that the rod is bent into a circle.

Previous measurements of the elasticity of glass have been carried out by Winkelmann and Schott, and later by Winkelmann himself. In these determinations very precise methods were employed for determining the deviation in the rod due to the load which was placed on it, despite the fact that some of the rods in question were from different meltings or contained bubbles, or were otherwise not completely homogeneous. In several instances the different results obtained by Winkelmann differ by amounts considerably greater than those found in the present investigation, so that the employment of refined methods of measurement was in some cases a waste of time.

In our measurements the rod was supported on two parallel horizontal knife edges, and a pan suspended from the centre by means of a fine wire 0·1 mm. in diameter. The rod was perpendicular to the knife edges and was also horizontal. Weights were placed in the pan and the depressions observed for varying loads up to 1 kg. The average depression for a load of 100 grams was thus determined, and the value of the elasticity constant (Young's modulus) calculated from the formula

---

* This JOURNAL, Trans., 1919, **3**, 126.

$$E = \frac{100 l^3}{12 \pi r^4 d},$$

where l is the distance between the knife edges, r the radius of the rod, and d the mean depression for 100 grams.

Several specimens of each glass were examined, and the length, l, was also varied. The mean of the values obtained for the different rods was accepted as the value of E for the glass of which they were made. The following is a specimen set of measurements:—

Glass.	Radius	Length.	Mean depression for 100 grams.	Average.	*E*.
6	0·2527 cm.	11·4 cm.	a. 0·00142 cm.	0·00143 cm.	6691 kg./mm.^{2}
			b. 0·00142 ,,		
			c. 0·00143 ,,		
		18·0 ,,	a. 0·00568 ,,	0·00569 ,,	6669 ,,
			b. 0·00569 ,,		
			c. 0·00569 ,,		
	0·2710 ,,	11·4 ,,	a. 0·00109 ,,	0·00109 ,,	6683 ,,
			b. 0·00109 ,,		
		18·0 ,,	a. 0·00428 ,,	0·00428 ,,	6702 ,,
			b. 0·00428 ,,		
	0·2260 ,,	11·4 ,,	a. 0·00222 ,,	0·00222 ,,	6726 ,,
			b. 0·00221 ,,		
			c. 0·00222 ,,		
		18·0 ,,	a. 0·00881 ,,	0·00881 ,,	6733 ,,
			b. 0·00881 ,,		
				Mean value	6700 kg./mm.

Results of the Measurements.

The measurements as carried out according to the methods already described are contained in Table I (p. 263).

For the sake of avoiding cross-references, the percentage composition of the glasses is also given. It will be noted that, with one exception, there is a continuous increase in the elasticity constant as the proportion of lime increases and that of soda diminishes, so that the conclusion can be drawn, in the first place, that lime imparts a far higher elasticity to glass than does soda. That is to say, strong evidence is afforded of what is known in practice, that a high lime glass is much stronger than one in which the soda is high and the amount of lime comparatively low.

TABLE I.

Variation of Young's Modulus Elasticity with Composition.

	Composition.						
Glass.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	Value of *E*.
1	74·25	0·42	0·16	Trace	—	25·37	5784 kg./mm.^{2}
2	73·90	0·21	0·14	1·57	—	23·80	5930 ,,
3	74·05	0·22	0·14	2·63	—	23·00	6175 ,,
4	74·02	0·29	0·15	3·79	—	23·15	6332 ,,
5	73·77	0·34	0·18	4·54	0·16	20·78	6426 ,,
6	73·21	0·55	0·62	6·22	0·22	19·38	6700 ,,
7	73·97	0·76	0·18	7·56	0·23	17·30	6804 ,,
8	74·82	0·38	0·09	8·15	0·26	16·30	6965 ,,
9	74·92	0·38	0·17	9·26	0·31	14·88	7034 ,,
10	74·59	0·48	0·17	10·40	0·29	14·22	7249 ,,
11	74·93	0·38	0·16	11·63	0·31	13·02	(6912) ,,
12	($6SiO_2$, 1·1CaO, 0·9Na_2O)						7642 ,,
16	66·67	1·43	0·32	18·06	0·85	12·72	8343 ,,

The one glass which appears to show a divergence from the rule is glass 11. It was expected that this deviation was accidental, and for this purpose determinations were repeated, but the earlier determinations were confirmed as the result. There is at present no explanation forthcoming why this sudden break should occur in the continuous increase of elasticity with the proportion of lime, and for the present, pending further confirmation, no stress is laid on it. If there is a real break, then it must be due to some special circumstance, since glasses with still higher proportions of lime exhibit a still greater elasticity. For example, a glass was specially prepared of the approximate chemical composition $6SiO_2$, 1·1CaO, 0·9Na_2O. It was found rather difficult to plain, and the rods drawn out were therefore not free from bubbles. Two of the best samples of rod gave values 7573 and 7711 kg./mm.^{2} respectively, or a mean value of 7642 kg./mm.^{2}. This value is probably slightly low, on account of the presence of bubbles. The result, at any rate, shows that with increasing lime content the strength still further increases. Further evidence of a similar character is obtained with glass 16, containing the greatest proportion of lime in the various glasses examined. In this particular case it will be noted that the elasticity is 8343 kg./mm.^{2}. The general conclusion, therefore, as to the effect of lime is borne out throughout the series.

Calculation of the Elasticity Coefficients.

Winkelmann and Schott drew the conclusion that it was possible to express the elasticity coefficient in terms of the contributions to the total elasticity made by each 1 per cent. of the constituent oxides. That is to say, $E = a_1z_1 + a_2z_2 + a_3z_3 + \ldots$; a_1, a_2, a_3 being the percentages of the constituent oxides, and z_1, z_2, z_3 the elasticity factors for these oxides, or the fraction of the total elasticity which each 1 per cent. of the oxide contributes.

It seemed of interest to us to calculate the elasticity coefficients of our series of lime-soda glasses using these factors, since some of the series of constants derived by the Jena workers are at least open to doubt in regard to their general validity. Table II contains the results of the calculation.

TABLE II.

Calculation of E using Winkelmann and Schott's Factors.

Glass.	*E* (calculated).	*E* (experimental).	Percentage difference.
1	7430 kg./mm.^{2}	5784 kg./mm ^{2}	−28·4
2	7374 ,,	5930 ,,	−24·2
3	7411 ,,	6175 ,,	−20·1
4	7386 ,,	6332 ,,	−16·6
5	7477 ,,	6426 ,,	−16·5
6	7548 ,,	6700 ,,	−12·6
7	7553 ,,	6804 ,,	−11·0
8	7495 ,,	6965 ,,	− 7·6
9	7530 ,,	7034 ,,	− 7·0
10	7521 ,,	7249 ,,	− 3·7
11	7582 ,,	6912 ,,	− 9·7
16	7640 ,,	8243 ,,	+ 8·4

It will be noted that there is great divergence between the results we have found by experiment and those derived by calculation, using Winkelmann and Schott's factors.

Indeed, whereas there is steady and notable increase in the elasticity with increasing the amount of lime, it will be noted that in the calculated values the increase is comparatively trifling and is unsteady. Moreover, as will be seen from Table III, Winkelmann and Schott concluded that soda and lime have the same effect in altering the elasticity of a glass. This is totally at variance with our experimental results, so that Winkelmann and Schott's factors for soda and lime are useless.

Without proceeding too far with the subject, in view of the limited number of three-component glasses which we have yet tested, we have attempted to assign values to the specific oxides entering into the composition of our glasses, and these values are given in the column of Table III, under the heading of "New Factor."

TABLE III.

Factors for the Calculation of Elasticity (Young's Modulus).

Oxide.	W. & Schott's factor.	New factor.
SiO_2	65	40
Na_2O	100	110
Al_2O_3	160	120
Fe_2O_3	—	120
CaO	100	240
MgO	500	300

The values of the factors Al_2O_3, Fe_2O_3, and MgO are uncertain, but considerable variation would not matter in the present case, since the amounts are exceedingly small. Thus, even if the factor for Fe_2O_3 were increased to 300 instead of to 120, the amount of it present is so small that the elasticity value would not be altered by more than about 0·5 per cent.

Using the new factor, the elasticities were recalculated, the results being given in Table IV.

TABLE IV.

Recalculation of Elasticities by New Factors.

Glass.	*E* (calculated).	*E* (experiment).	Percentage difference.
1	5831 kg./mm.^{2}	5784 kg./mm.^{2}	−0·8
2	5993 ,,	5930 ,,	−1·1
3	6166 ,,	6175 ,,	+0·1
4	6289 ,,	6332 ,,	+0·7
5	6436 ,,	6426 ,,	−0·1
6	6759 ,,	6700 ,,	−0·9
7	6858 ,,	6804 ,,	−0·8
8	6879 ,,	6965 ,,	+1·2
9	7015 ,,	7034 ,,	+0·3
10	7219 ,,	7249 ,,	+0·4
11	7378 ,,	6912 ,,	−6·7
16	8611 ,,	8343 ,,	−3·2

The agreement is quite good, the biggest divergence being found in the case of glass 11.

Summary and Conclusion.

As a result of a series of measurements on thirteen different lime-soda glasses of regular variation in composition, it has been shown that:—

(1) The regular increase in the amount of lime present causes a continuous and very marked increase in the elasticity of the glass.

(2) The conclusions of Winkelmann and Schott, which suggest that lime and soda are but little different in their effects on the elasticity, are incorrect.

(3) New factors were derived by which it was possible to calculate the elasticity of a simple series of lime-soda glasses.

Department of Glass Technology,
The University, Sheffield.

XXIX.—*Some Experiments on Glass for Lamp-working Purposes.*

By J. D. Cauwood, M.Sc., J. H. Davidson, M.Sc., F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

The problem of discovering a really suitable glass for lamp-working purposes was one that was urged on us soon after the research work of this Department began in 1916. The number of other pressing needs, however, precluded much progress being made. In 1917 we were asked to investigate the subject of a special glass for all-glass syringes, and since that date a number of experiments have been conducted, with results that may now be usefully stated, despite their incompleteness.

In March, 1919, a bulletin was issued from the Department to certain manufacturers interested in lamp-working glass, containing the results of analyses made by us of a number of foreign glasses of good repute. The compositions, with notes on their sources, are as follows:—

Composition of Foreign Lamp-working Glasses.

	(1).	(2).	(3).	(4).	(5).	(6).
SiO_2	69·30	69·10	71·88	68·78	61·26	71·90
As_2O_5	Trace	0·10	0·10	—	—	—
Sb_2O_3	—	—	—	0·52	3·45	0·48
Al_2O_3	4·05	3·10	2·75	4·04	7·92	3·69
CaO	8·28	6·89	4·90	7·75	9·25	7·99
MgO	0·07	0·20	0·20	0·34	0·20	—
K_2O	4·96	6·38	1·98	2·60	3·98	0·32
Na_2O	12·80	14·50	18·57	15·72	13·08	14·90
MnO	0·20	0·10	0·10	0·20	0·30	0·75
Fe_2O_3	0·18	—	—	0·25	0·30	0·31
	99·84	100·37	100·48	100·20	99·74	100·34

No. 1 was obtained from Mr. E. Preston, Barker's Pool, Sheffield, as a sample of good German lamp-working tubing.

No. 2 from Mr. C. F. Thackray, of Leeds, as a special German tubing (Dewitt and Herz, Berlin), suitable for all-glass syringes.

No. 3 from Mr. Thackray, described as a fairly successful French tubing intended for the same purpose as No. 2.

No. 4, Austrian tubing for X-ray bulbs.

No. 5, German tubing, used by C. E. Muller, of Coburg.

No. 6, German tubing used for mine horns. The tubing had two brown lines running vertically down the tube, accounting probably for the rather high manganese content.

Nos. 4, 5, and 6 were supplied to us by Dr. M. W. Travers, F.R.S.

The amount of the tubing available in each case was so small as to provide little more than enough for chemical analyses, but certainly insufficient to make a test of the lamp-working properties. Accordingly, it became desirable to reproduce, as nearly as possible, samples of the above types by making meltings on a sufficiently large scale for the production of specimens which could be worked up in the lamp into a variety of articles so that a thorough test could be performed.

In addition to the meltings made to test the glasses 1—4 and 6 (glasses based on No. 5 being purposely omitted because of the blackening produced on antimony-containing glasses), others were carried out to elucidate the effect of certain materials in affecting discoloration and of different types of blowpipe flame.

I. *Glasses based on Reputable Foreign Lamp-working Glasses.*

The preparation of different samples of glass was carried out in the manner already described in other papers from this Department, in closed pots of 56 lb. capacity.

Glasses based on Analysis No. 1.

Two batches were melted, differing only in respect to the arsenic and the manganese contents. They were:—

Glass No. :	343	347
Sand	1000	
Felspar	523	
Limespar	286	
Soda-ash (95%)	415	
Potash (92%)	108	
Magnesia (90%)	1·4	
Arsenic	4	—
Manganese (87%)	5·5	2·75

Both melted readily and were easy to fine, and finally were easy to work out into tubing. In the lamp they worked distinctly hard, No. 347 less so than No. 343. The use of different types of blowpipe led to somewhat varying results. No. 343 in all cases was discoloured by darkening, whilst No. 347 was unaffected. With both the ordinary and an injector blowpipe, No. 343 developed a bloom, whereas with No. 347 the bloom was only very slight. Glass No. 343 yielded best results in a blowpipe with pre-heated (electrically) flame, and worst with an oxy-coal gas flame. On the other hand, No. 347 showed thick bloom in the preheated flame with some devitrification, both faults being intensified in the oxy-coal gas flame. On the whole, however, for ordinary purposes, No. 347 was the better glass, though not soft enough for really satisfactory work.

Glasses conforming to Analysis No. 2.

The favourable report of this glass given by Mr. Thackray led us to carry out quite a considerable number of meltings, some of batches corresponding closely with the analytical composition and others introducing variations. The ones described below are based precisely on the composition determined by analysis.

Glass No.:	14.	15.	344.	373.
Sand	1000	1000	1000	1000
Felspar	—	380	367	367
Limespar	180	220	220	220
Soda-ash (95%)	380	450	448	448
Potash	140	137	151 (92%)	151
Magnesia (90%)	3	4	3·7	3·7
White Arsenic	2·5	3	5·5	—
Manganese (87%)	4	5	2·5	2·75
Hydrated Alumina (Loss 34·89%).	65	—	—	—

Batch No. 14 may be described as a straight batch, in which the potash was added in a simple form and the alumina as hydrated alumina. In the three others all the alumina was added as felspar and as much as possible of the potash. In Nos. 344 and 373, except for a very slight readjustment of the potash and the felspar, the difference lies in the presence of arsenic in the former and the entire absence in the latter.

No. 14 worked from the pot very easily at temperatures between 1150° and 950°. No. 15, though working quite well, was less easy to manipulate, and called for a higher working temperature.

In the blowpipe flame both glasses became discoloured, but worked easily. Bloom appeared on both glasses, but was much more pronounced on No. 15 than on No. 14, whilst on blowing and re-blowing a bulb, No. 15 showed signs of devitrification much sooner than No. 14.

As regards Nos. 344 and 373, the former perhaps melted and fined slightly quicker than No. 373, as might be expected from the presence of arsenic. There was no noticeable difference so far as working and actual tubing-drawing were concerned, both glasses being manipulated easily at temperatures between 1300° and 1100°, the best temperature being about 1200°.

In the blowpipe flame No. 344 showed a brown discoloration at the first blowing; there was no discoloration with No. 373. Both glasses were easy to work in the flame, being inclined rather to the soft than to the hard side. Bloom on No. 344 was greater than that on No. 373; in fact, on No. 373 there was scarcely any mark. Whereas No. 344 showed signs of devitrification on being reheated about fifteen times, besides being very discoloured, No. 373 showed no signs of devitrification on the blown bulb even after thirty re-heats. On the tube, however, below the bulb made from No. 373, after thirty re-heats the bloom was quite plain and appeared to be due to definite crystallisation.

To sum up, all the four glasses showed excellent lamp-working properties so far as ease and speed of manipulation are concerned. All the arsenic-containing glasses were, however, marred by blackening, whilst all but No. 373 developed a distinct bloom when worked in the flame. No. 373, whilst not perfect in this last respect, was very good, and the best glass of the series.

Glass corresponding with Analysis No. 3.

Glass No. 345.

Sand	1000	Potash (92%).........	24
Felspar	303	Magnesia (90%)	3·8
Limespar.....................	144	White Arsenic	8·5
Soda-ash (95%)	542	Manganese	2·5

The batch melted, fined, and worked quite as easily, probably more easily, than any of the batches previously mentioned.

There was a discoloration and definite bloom on the tube at the first blowing. Articles made from this showed these defects, but the glass worked excellently in the flame. It was, perhaps, a little harder than No. 373.

Glasses corresponding with Analysis No. 4.

In both of the following batches the alumina was introduced as felspar. The only differences were due to slight variations in amounts of several constituents.

Glass No. :	40.	346.
Sand	1000	1000
Felspar	535	528
Limespar	270	270
Soda-ash (95%)	505	526
Potash (92%)	26	31
Magnesia (90%)	6	7·5
Antimony oxide	10	12
Manganese (87%)	8	5·5

Both batches melted fairly readily, but were not easy to plain. No. 346 worked a little more easily than No. 40.

In the blowpipe flame both glasses became very dark coloured, with bloom rather more extensive than on any glasses based on analyses Nos. 1 to 3. The glasses were rather hard, but not quite so hard as No. 343; No. 346 appeared to "gather" better than No. 40.

Glass corresponding with Analysis No. 6.

Glass No. 42.

Sand	1000	Antimony oxide	7
Soda-ash (95%)	380	Manganese (87%)	7
Limespar	200	Hydrated alumina	82

Melting occurred fairly easily, but the glass was somewhat difficult to work owing to rapid increase in viscosity. The hot metal appeared dark and opaque, but yielded a bright glass when cold, with a brown tinge when viewed in thick sections.

In the blowpipe the glass turned a dark yellowish-brown colour and bloomed extensively.

Devitrification was apparent after eight re-heatings. Whilst neither particularly hard nor soft to work, the glass was not easy to manipulate, since it set rather rapidly.

II. *Other Lamp-working Glasses.*

From time to time quite a large number of meltings of glasses for lamp-working purposes have been carried out, and some of them are described below.

A. *Glasses based on Analysis No. 2.*

A number of variants have been tried, of which the following five are quoted. The differences of compositions are obvious from the table, but it may be remarked that No. 13 corresponds with analysis No. 2, except that the potash has been replaced entirely by its equivalent in soda.

Glass No.:	13.	41.	43.	398.	399.
Sand	1000	1000	1000	1000	1000
Felspar	—	420	350	364	367
Limespar	180	220	150	218	220
Sodium nitrate	—	—	—	—	170
Soda-ash (95%)	500	450	600	391	321
Potash (92%)	—	140	—	150	147
Magnesia (90%)	3	10	20	4·5	3·5
White Arsenic	2·5	—	10	—	5·5
Antimony oxide	—	5	—	—	—
Manganese	4	5	7	3	2
Hydrated alumina	65	—	—	—	—

No. 13 worked easily. No. 41 proved too stiff to work at 1150°, and needed to be worked at 1300—1200°. It melted fairly easily, but did not fine so readily as other batches based on analysis No. 2.

With No. 43 there was tendency to "raggedness" in the tubing, possibly due to the magnesia, and a temperature of 1350—1300° was required for good working.

No. 398 melted fairly readily, but was very difficult to fine. The metal was very viscous and difficult to draw into tubing, even at 1300°. No. 399 melted and fined quickly, whilst it worked very easily at 1200—1100°, although it set fairly rapidly. In regard to lamp-working, No. 13 was fairly soft and worked easily in the lamp. Discoloration and slight bloom were the defects. It was softer than No. 344, but slightly harder than No. 373. No. 41 was a trifle hard, showed bad discoloration, and extensive bloom, and devitrified quickly. No. 43 worked and "gathered" well, but turned brown. It did not appear to devitrify readily, but bloom was evident. No. 398, containing no arsenic or antimony, showed no discoloration, but the bloom was thick and there was evident devitrification. No. 399 was in general working properties similar to No. 373, but turned brown directly and showed a slight bloom which rapidly increased on repeated heating.

B. *High Lime Glass.*

In an earlier communication,* it was stated that a bottle glass with high lime content had behaved unexpectedly well when heated in the blowpipe, and might be further improved by modification. The original glass (No. 17) and its modification (No. 372) are as follows:—

Glass No.:	17.	372.
Sand	1000	1000
Limespar	450	350
Soda-ash (95%)	300	200
Potash (92%)	—	140
White Arsenic	7	7
Manganese (87%)	—	3
Hydrated alumina	—	87

---

* J. H. Davidson and W. E. S. Turner, this vol., Trans., p. 225.

No. 372 melted readily, but was not easy to fine, whilst it had to be worked above 1250°, owing to the rapid increase in viscosity. In the lamp the tubing proved rather hard, but not *too* hard for fairly quick working. It discoloured readily, but only a very slight trace of bloom was produced, and with the omission of arsenic would probably make good working tubing.

C. *Soft Soda Tubing.*

Some melts in which all the alkali was soda, and not a mixture of soda and potash, have already been recorded by us. The following batch was also tested:—

Glass No.:	72.
Sand	1000
Felspar	350
Limespar	150
Soda-ash (95%)	600
Magnesia (90%)	20
White Arsenic	10
Manganese (87%)	7

Melting easily took place at 1400° and the glass worked fairly well at 1350—1300°, though with a tendency to cordiness below that temperature. The tubing so produced was fairly soft, similar to No. 373, easy to work, but gave a bloom and discoloured badly, due again to arsenic.

Discussion of Results.

From the considerable number of experiments which we have carried out, certain definite conclusions can be drawn, whilst some points call for a little further investigation.

(1) A consideration of the glasses so far examined indicates that probably the best for general purposes so far obtained belong to the types having compositions corresponding with analyses Nos. 1—3. Of these three, in turn, those based on analysis No. 2 are accorded first place, and certainly the best all-round glass made by us was based on No. 2.

This liking of German lampworkers for a glass of such a composition is shown by other samples in our possession. Thus, we have been called on to reproduce a lens glass for artificial eyes suitable for combining with an opal tubing of a certain composition. On analysis, this lens glass was found to contain:—

SiO_2	68·56	per cent.
Sb_2O_3	0·27	,,
Al_2O_3	2·54	,,
CaO	6·62	,,
MgO	0·43	,,
K_2O	10·15	,,
Na_2O	11·02	,,
MnO	0·10	,,
Fe_2O_3	0·29	,,

This composition will be found to correspond more nearly with analysis No. 2 than any other, the main difference being in the use of correspondingly more potash, the total alkalis being almost the same. For its reproduction a number of batches were tested, the two best being:—

Glass No. :	49.	50.	Glass No. :	49.	50
Sand	1000	1000	Potash (92%).........	205	205
Felspar	300	300	Magnesia...............	10	10
Limespar	110	110	Antimony oxide ...	—	2
Sodium nitre	—	50	~~White~~ Arsenious oxide	5	—
Soda-ash (95%) ...	375	335	Manganese dioxide .	3	1

No. 49 closely reproduced the original German glass and worked well save for the discoloration due to the arsenious oxide. No. 50 was a little harder, but not discoloured so seriously as No. 49.

(2) Between the various glasses which were made and worked in the blowpipe, it was not always possible with certainty to distinguish and classify their working properties. Very roughly, however, the following is the order of excellence, beginning with the best in each set.

(*a*) Neglecting discoloration.			(*b*) Including discoloration.		
373	399	346	373	345	346
43	42	40	347	343	40
14	344	41	398	399	43
13	345	347	14	41	42
15	—	343	13	372	—
—	—	372	15	—	—
—	—	398	344	—	—

As discoloration can be avoided by leaving out arsenic and antimony oxides, we consider that list (*a*) should be given more weight.

(3) From the experiments made up to the present, we are forced to the conclusion that both arsenic and antimony should be omitted from lamp-working glasses, since all samples we have prepared with these elements present give blackening when worked in the flame.

This conclusion in some respects may be open to slight doubt. Thus, whilst some of the good foreign glasses contain no arsenic or antimony, six of those recorded in this paper contain one or other of these elements, one of them (analysis No. 5) containing no less than 3·45 per cent. We were led to inquire if the mode of preparation of the glass, for example, the presence of adequate oxidising materials, might cause any difference. For this purpose the effect of the addition of nitre was tested, but this material was not found to make any appreciable difference to the tendency to blacken.

Doubt has been raised as to whether or not the blackening might be attributed to traces of lead oxide as impurity in the arsenic or antimony oxide. In regard to the former, no trace of lead was discovered to be present on test. The antimony oxide had the following composition:—

Lead oxide	0·22 per cent.
Insoluble matter (ignited)	0·18 ,, ,,
,, ,, (volatile, probably Sb_2O_3) ...	0·04 ,, ,,
Antimony oxide (by difference)	99·56 ,, ,,

No trace of arsenic in the antimony oxide was detected by the magnesia mixture test.

The amount of lead oxide present amounts to 2 parts per 1000 of the antimony oxide used. As 1 part of antimony oxide per 1000 of batch was found to cause blackening, the influence of lead, it will be evident, would have to be extraordinarily great to be the cause of blackening in the present instances, and it is highly doubtful if the trouble can be assigned to it. In any case, commercial antimony oxide is scarcely likely to be purer than the sample stated, and clearly, therefore, this oxide may be a source of danger in any case. The actual effect of lead can only be tested by obtaining absolutely pure antimony oxide and adding it to a batch, first alone, and afterwards with exceedingly small amounts of lead oxide.

If antimony oxide is the cause of blackening, we are still left in doubt as to the use or mode of working of glass of analysis No. 5. We have tested all these glasses with four different types of blowpipe; the ordinary type, a new injector type, one with preheated flame, and the oxy-coal gas blowpipe. Although slight differences occurred from glass to glass, the burner which seemed best to suit most types was the ordinary burner, the others tending to accentuate any defects.

(4) Finally, it may be quite possible that other types of glass suitable for lamp-working may be developed besides those approximating analyses Nos. 1—3 or even 1—6. Thus, our experiments with glasses Nos. 17 and 372 show that a high lime-containing glass is not necessarily a bad glass from the lamp-working point of view.

We have been making experiments in other directions also, and may here note a result of considerable interest. For the purpose of one of the series of researches in progress in the Department, we have had occasion to prepare specimens of lime glasses with soda and with potash respectively, and also with varying proportions of both soda and potash. On testing samples of these glasses in the flame, we found that the one containing soda and potash in equimolecular proportions worked extraordinarily well and indicates a new direction for research on lamp-working glasses.

Department of Glass Technology,
The University, Sheffield.

XXX.—*Magnesia–Soda Glasses.*

By J. H. Davidson, M.Sc., F. W. Hodkin, B.Sc., and
W. E. S. Turner, D.Sc.

Magnesia glasses do not as yet find a place in commercial manufacture in the same sense as lime glasses; that is to say, three component glasses of magnesia, soda, and silica have no place corresponding with those of lime, soda, and silica. Since, however, magnesia is naturally found associated with lime, there are few lime glasses which do not contain some very small quantity of it at least. In certain districts the limestone drawn on for bottle-glass production is dolomitic, so that, whether the glass-maker is aware of it or not, one-half equivalent of the lime has been introduced as magnesia.

Whether magnesia glasses ever become normal articles of commerce will depend first on whether or not magnesia glasses possess distinct advantages over other types, and, secondly, on the possibility of a cheap source of magnesia. As already remarked, magnesia already is used in conjunction with lime by some glass-bottle manufacturers, whilst, since it is believed to reduce, relatively, the expansion of glass, it has found application in the manufacture of chemical and of heat-resisting glasses.

As a sequel to our investigation of the physical properties of the lime–soda series, we have undertaken the examination of corresponding magnesia–soda glasses. The general molecular type was, as before, that of the tri-silicate glasses, and the range from $6SiO_2,2Na_2O$ to $6SiO_2,0{\cdot}9Na_2O,1{\cdot}1MgO$ was successfully prepared and tested. The actual batch compositions employed are stated in Table I. The numbers of the glasses are our own serial numbers.

Table I.

Glass No. :	24.	25.	26.	27.	28.	
Sand	1000	1000	1000	1000	1000	
Magnesia	12·4	24·7	37	49·4	61·8	
Soda-ash	560	529	500	471	441	
Glass No. :	**329.**	**330.**	**331.**	**332.**	**389.**	**390.**
Sand	1000	1000	1000	1000	1000	1000
Magnesia	74·1	865	99	111	123·5	136
Soda-ash	412	282	352	324	294	265

One other glass (No. 35) was prepared, using 148 parts by weight of magnesia and 235 of soda-ash per 1000 of sand, but it was so difficult to work from a pot that the tubing, rod, and other articles produced were of poor quality only.

The magnesia was employed in the form of the calcined oxide. The percentage composition was found to be: MgO, 91·00; CaO, 2·40; Al_2O_3, 0·07; Fe_2O_3, 0·06; matter insoluble in HCl 0·05, and loss on ignition 6·44. (In setting out the batch compositions above, the quantities of magnesia stated are those of the perfectly ignited material.) The soda-ash contained 1·02 per cent. of NaCl and 0·17 per cent. of Na_2SO_4. The batch quantities stated are for the dry material.

The melting was carried out in closed pots of 56 lb. capacity with thorough stirring, assisted by repeated boiling out with ammonium nitrate, whilst the homogeneity of the glasses was controlled by density measurements and by analyses of different portions.

Information on the working properties of the glasses is stated in Table II.

TABLE II.

Glass No.	Approx. molecular composition.	Working properties.
24	$6SiO_2$, $1{\cdot}9Na_2O$, $0{\cdot}1MgO$.	At 1100—1200° very mobile. Did not cool so rapidly as the corresponding lime-glass.
25	$6SiO_2$, $1{\cdot}8Na_2O$, $0{\cdot}2MgO$.	Very mobile at 1200—1300°, but worked well.
26	$6SiO_2$, $1{\cdot}7Na_2O$, $0{\cdot}3MgO$.	Similar to 25. Retained its heat for considerable time.
27	$6SiO_2$, $1{\cdot}6Na_2O$, $0{\cdot}4MgO$.	Similar to 26.
28	$6SiO_2$, $1{\cdot}5Na_2O$, $0{\cdot}5MgO$.	Worked well and retained its heat.
329	$6SiO_2$, $1{\cdot}4Na_2O$, $0{\cdot}6MgO$.	Worked well at 1150—1200°. Thick foam on surface of glass requiring to be removed.
330	$6SiO_2$, $1{\cdot}3Na_2O$, $0{\cdot}7MgO$.	Worked well at 1150—1250°. Rather viscous and needed temperature of 1300° to enable to pour. Slight scum.
331	$6SiO_2$, $1{\cdot}2Na_2O$, $0{\cdot}8MgO$.	Melted 1400—1450°. Worked well at 1250—1350°. Viscous and stiff, but drew evenly into rod and tubing.
332	$6SiO_2$, $1{\cdot}1Na_2O$, $0{\cdot}9MgO$.	Similar to 331, but somewhat more viscous.
389	$6SiO_2$, $1{\cdot}0Na_2O$, $1{\cdot}0MgO$.	Metal very viscous even at 1400°, and inclined to be seedy and cordy. Tubing difficult to draw.
390	$6SiO_2$, $0{\cdot}9Na_2O$, $1{\cdot}1MgO$.	Very viscous. Boil difficult to remove even after 22 hours. Scum on surface. Easy enough to gather, but too stiff to draw even at red heat and tubing and rod not good.

Glasses Nos. 28—389 had a light blue tint.

The lamp-working properties of the tubing obtained were also tested, but the results for corresponding lime and magnesia glasses were so similar as to call for no further detail. If anything, the magnesia glasses were a trifle harder, but even this point was difficult to test with certainty.

Some of the results set out in Table II have been, in the authors' experience, borne out in tank furnaces melting a high lime glass for bottle manufacture, where the lime has been dolomitic and therefore one-half magnesia. In one case, where excess had been added, a boil was found difficult to get rid of, whilst the blue tint referred to was also noticed.

It will be noticed that in a number of respects magnesia resembles lime in the properties it bestows on glass. Thus, with magnesia in large quantities the glass is not easy to melt. The lamp-working properties are much the same, and, so far, we have not discovered any striking difference between the chemical resistance of the two kinds of glass.

On the other hand, there are some distinct differences. The viscosity of the glasses containing large quantities of magnesia is undoubtedly greater than that of the corresponding lime glasses, which, at high temperatures, are very fluid. The actual rate of change of viscosity, however, seems to be less with the magnesia glasses than with the lime. Magnesia glasses also retain their heat to a considerably greater degree, the moils on the gathering iron being tough and not easy to remove without quenching. There is also a tendency to raggedness or stringyness, which is not shown by lime glasses, and probably a greater tendency to cordiness. The retention of heat and the somewhat larger viscosity or working range give magnesia glasses some advantage over those of lime. Other advantages so far brought to light in our investigations include a lower coefficient of expansion for heat and a lower annealing temperature. Thus, a thorough study of the properties of the magnesia glasses may prove fruitful.

Department of Glass Technology,
The University, Sheffield.

XXXI.—*The Annealing Temperatures of Magnesia-soda Glasses.*

By S. ENGLISH, M.Sc., and W. E. S. TURNER, D.Sc.

IN continuation of our work on the relation between the composition of a glass and the temperature required for annealing, we have determined the upper annealing temperature required to free magnesia glasses from strain at a reasonably rapid rate. The conditions under which the tests were carried out have been described previously.[*]

The composition of the glasses, as ascertained by analysis, is stated in detail in respect to the main constituents in table I. As indicated in the previous paper, the magnesia contained a small percentage of lime. The total amount of the three minor constituents, lime (CaO), iron oxide, and alumina, varied from 0·37 per cent. in glass No. 24 to 0·91 per cent. in No. 390 (0·50 per cent. being CaO in the latter).

TABLE I.

Glass No.	SiO_2.	Na_2O.	MgO.	Minor constituents (CaO, Fe_2O_3. and Al_2O_3).	Total.
24	74·07	24·23	1·10	0·37	99·87
25	74·35	23·46	1·85	0·75	100·41
26	75·00	22·12	2·49	0·26	99·97
27	75·16	20·69	3·47	0·46	99·78
28	75·19	19·83	4·20	0·52	99·74
329	76·30	18·26	5·09	0·74	100·39
330	77·09	16·05	6·10	0·68	99·92
331	76·68	15·77	6·87	0·93	100·25
332	76·86	14·55	7·46	0·93	99·80
389	77·77	13·40	8·45	0·56	100·17
390	78·28	11·76	9·30	0·91	100·25

The numbers by which the glasses are designated are our own serial numbers. If the actual compositions of the glasses followed precisely those intended, based on the continuous molecular variation in the series $6SiO_2,2Na_2O$ to $6SiO_2,0{\cdot}9Na_2O,1{\cdot}1MgO$, the actual percentage of silica present should increase regularly from 74·38 to 78·26 per cent. It will be seen that the increase is somewhat irregular. Under commercial conditions of preparation, as in the present instance, the small amounts of impurity in the raw materials and the absorption of clay from the pot disturb the perfect sequence in the changing compositions. In estimating the effect of small amounts of impurity and of the variation of composition from that intended, regard must be paid first of all to the experimental accuracy attainable in the measurement of the annealing temperature, and secondly to the effect which known variations of composition bring out.

---

[*] This JOURNAL, Trans., 1918, **2**, 90; 1919, **3**, 125.

In regard to the first, the annealing temperature is not one that can be determined with precision like the melting point of a pure substance. The results recorded are the average of at least two determinations on separate samples of glass. Such determinations as a rule did not differ by more than 3°. Provided the magnesia content ascends fairly closely as required, other slight differences in composition do not appear important. This not only appears to be true because of the comparatively small advance in annealing temperature for each 0·1 molecule increase of MgO, but was also demonstrated by the fact that the corresponding glasses in duplicate series of meltings gave results in which the greatest difference of annealing temperature was only 3°, coincidence actually being noted in some cases.

The slight departures from the intended molecular proportions are therefore held, within the limits of experimental error, to be without noteworthy effect.

The annealing temperatures found are recorded in table II. Since, in the graphic representation of the results which follow, making comparison of the magnesia with the lime glasses, the molecular composition of the glasses and not the ordinary percentage composition by weight should be made the basis of comparison, we have set out the annealing temperatures of both the magnesia and the lime glasses side by side with the percentage number of molecules of the oxides present in each case.

TABLE II.

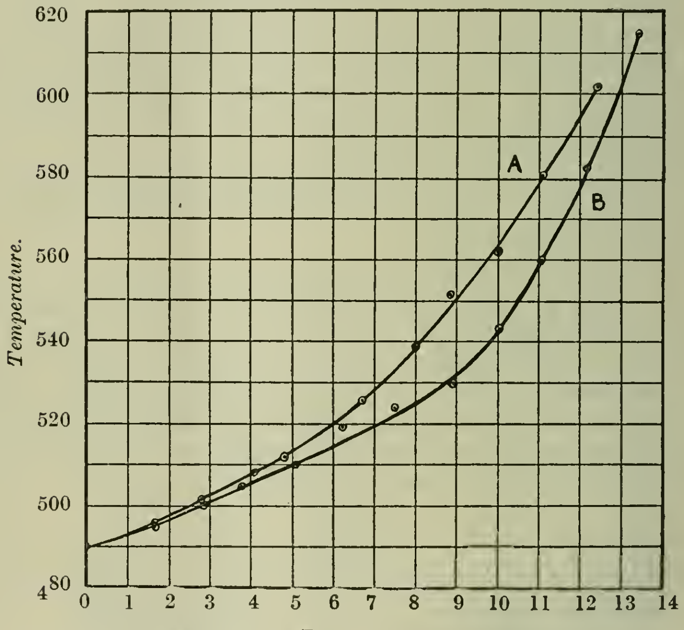
Variation of Annealing Temperature with Composition.

Magnesia-soda glasses.			Lime-soda glasses.		
Glass No.	Molecular percentage of magnesia (MgO).	Annealing temperature.	Glass No.	Molecular percentage of lime.	Annealing temperature.
1	—	490°	1	—	490°
24	1·66	495	2	1·62	496
25	2·77	502	3	2·81	501
26	3·71	505	4	4·11	508
27	5·16	510	5	4·84	512
28	6·23	519	6	6·73	526
329	7·48	524	7	8·00	538
330	8·95	530	8	8·75	552
331	10·02	543	9	10·01	562
332	11·01	560	10	11·14	581
389	12·21	583	11	12·41	601
390	13·38	616	—	—	—

It will be noted that with the magnesia glasses the effect in raising the annealing temperature is not rapid in the early stages. After glasses Nos. 329 and 330, however, the magnesia begins to make its influence felt in a much more marked manner, and past this point rapid increase in the annealing temperature occurs with each successive addition of approximately one molecular percentage of magnesia.

More interesting is it to compare the behaviour of the lime and the magnesia glasses. This may be done approximately in the table itself, but perhaps to better advantage in the curves attached. It may be noted here that, subsequent to the previous publication on this subject, a number of additional determinations have been made on the lime-soda glasses, including tests on new samples of glass No. 1, and these tests have led to some revision of the earlier values for the annealing temperatures (glasses Nos. 1 to 4).

A—*Lime-soda Glasses.*
B—*Magnesia-soda Glasses.*



Molecules per cent. of MgO *or* CaO.

From the curves two things are apparent. First, the rate of increase of annealing temperature is, for the softer glasses, greater with the lime glasses than with the magnesia glasses. With the hardest glasses, however, there is a suggestion that the curves for still higher proportions of lime and magnesia might approach or even intersect one another, when the increase of annealing temperature might become greater with the magnesia glasses. Only additional experiments, outside the range of easily workable glasses, could ascertain this, and the results would probably be of academic rather than of practical interest.

As the curves stand, however, they do suggest an interesting connection. If reference is made to the work of A. L. Feild * on the viscosity of fused slags or silicates containing lime or magnesia, as the case may be, it will be noted that the viscosity curves for molten calcium and magnesium silicates are not unlike the two representing the variation of annealing temperature. Although it does not follow that the viscosity curves at lower temperatures than those employed by Feild would preserve the same relationship as found at high temperatures, it is nevertheless natural to expect some connection between viscosity and annealing temperature, since annealing of a glass can only take place readily when incipient softening has set in. Viscosity measurements on lime and magnesia glasses of the above composition ranges would therefore be of interest for this, among other reasons.

Secondly, it will be clear, both from the table and from the curves, that in corresponding glasses, namely, in those containing equimolecular proportions of lime or of magnesia, the magnesia glasses are easier to anneal; that is, can be annealed at a lower temperature than the lime glasses. If, therefore, in a commercial glass, dolomitic limestone or lime should be used either wholly or partly as a substitute for ordinary limestone or lime, within the range of compositions given above, the resulting glass may be expected to be capable of more ready annealing. Comparison of the above two curves would probably indicate the required annealing temperature for a glass containing a known proportion of dolomitic lime.

DEPARTMENT OF GLASS TECHNOLOGY,
THE UNIVERSITY, SHEFFIELD.

---

* A. L. Feild, *Trans. Faraday Soc.*, 1917, **13**, 3; see also W. E. S. Turner, *J. Soc. Glass Tech.* 1919, **3**, 46.

XXXII.—*Note on the Formation of Glass.*

By S. C. Bradford, B.Sc.

Although it has been customary for many years to regard glass as a supercooled liquid, the supposition does not appear to yield much helpful suggestion in glass technology, neither does it conform to the dictionary definition of a liquid as being in a state in which its particles are free to travel about. Comparison with a typical supercooled liquid, such as phenol below its melting point, makes the differences obvious: the former is sufficiently solid to have universal application for the manufacture of vessels, while the latter is a mobile fluid and its crystallisation is marked by the sudden disappearance of the mobility.

There is no such sudden change in the solidification of glass; the gradual transition from liquid to solid resembles the setting of a jelly. Indeed, the similarity of glass and gels has previously been pointed out. The structure of gels is now beginning to be understood, and similar considerations appear to explain the formation of glass. Most solid substances exhibit the property of plasticity in a greater or less degree. It is well known that long glass rods or tubes tend to bend under their own weight in the course of years. Lead pipes do the same in a greater degree. But although plasticity is an important physical property of glass, it is a characteristic of solid substances rather than of liquids. The same phenomenon is marked in the case of gels and other substances, such as resins and pitch, which are recognised to be colloidal in nature.

The researches of von Weimarn lead almost inevitably to the conclusion that no substances are truly amorphous. All solid bodies are really crystalline. The amorphous or colloid condition is merely one in which the crystals are so small as to be invisible, and von Weimarn has deduced a simple empirical formula which determines the size of the crystals which appear in a given case. This is inversely proportional to the number of centres of crystallisation produced. If numerous enough, the crystals become so small as to be invisible in the microscope, and the substance is said to be amorphous or colloidal.

From the examination of a large number of precipitates, von Weimarn found that the number of crystallisation centres, N, is represented by the relation

$$N = K\frac{P}{L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(i)}$$

where L is the solubility, P the excess concentration $(C - L)$ of the substance which will appear in the solid state, and K is a variable which depends on the degree of aggregation of the reaction components in solution and the viscosity of the reaction medium. By the help of this relation, von Weimarn has been able to obtain a number of substances, such as barium sulphate, in the colloid condition which usually occur in the crystalline state. In a recent paper* the author has shown that this same formula is also sufficient to explain the reversible gelation of the natural gels, such as gelatin and agar, and it was pointed out that similar considerations must apply to glasses and resins.

In the case of the solidification of a melt, the formula becomes

$$N = K\frac{T - T}{R} \qquad \text{(ii)}$$

where $T - T_1$ is the absolute overcooling and R is the latent heat of crystallisation.

There are many indications that the solidification of glass is a crystallisation process. Numerous substances are known which can be obtained at will in either the glassy or the crystalline state. For instance, arsenic trioxide can be produced as a clear, transparent glass which slowly changes at the ordinary temperature into an opaque, white, crystalline substance resembling porcelain. The alkaloid piperine furnishes another example. It crystallises from alcohol in monoclinic prisms which melt at 132°. On cooling, the melted crystals set to a light yellow, transparent resin. On heating to 100°, the resin loses its transparency and becomes nearly opaque like sulphur, owing to its transformation into a mass of microscopic crystals, which undergo no further change until they melt at 132°. On cooling, the resin is formed as before. On keeping for about ten days, the resin begins to develop yellow, sulphur-like spots of these microscopic crystals, which gradually permeate the whole mass. The growth of visible crystals is due, apparently, to the tendency which larger crystals always show to develop at the expense of smaller ones. This is well exemplified by iodine. If a number of small crystals be sealed up in a tube and examined after some years, it will be found that the smaller crystals have disappeared and the larger ones greatly increased in size. The phenomenon is frequently observed in gels, which after a time commence to develop microscopic crystals, which gradually extend throughout the whole.

As Sir Herbert Jackson states,† glasses are known which show all degrees of readiness to crystallise. By rapid cooling of the molten mass, zinc silicate is obtained in the vitreous form which is stable for many years. By heating to a few degrees above its softening point, it changes to a translucent, crystalline mass. A more complicated glass of the formula $Na_2O,CaO,8SiO_2$ passes, on cooling, through a stage of marked opalescence, finally appearing as a mass of crystalline nodules.

---

* *Biochem. J.*, 1918, **12**, 352.

† *J. R. Soc. Arts*, 1920, **68**, 134.

The development of visible crystals is dependent on the velocity of crystallisation. From their low thermal conductivity and viscosity, glasses must have a very small velocity of crystallisation, which would allow the development of a great degree of overcooling. In conjunction with great viscosity and molecular aggregation, represented by a large K in formula (ii), this would lead, in most cases, to the eventual production of so many crystallisation centres as to yield a colloidal substance.

If the formation of glass is really a crystallisation process, it would be expected that it would be influenced by the well-known series of anions and cations which affect the physical properties alike of colloid and true solutions.* For instance, the gelation temperature of gelatin is depressed by anions in the order:

$$CNS > I > NO_3 > Br > Cl > SO_4 > CO_3,$$

and the coagulation (that is, crystallisation) of suspensoids is affected by cations of the order:

$$H > Cs > Rb > NH_4 > K > Na > Li.$$

All the physical properties of gels and solutions appear to be influenced by ions in almost exactly the same order. So far, only a comparatively limited number of ions have been studied, but it appears to be a general rule that monovalent ions are the least effective, divalent ions more so, the action increasing enormously with the valency. The extraordinary effect of the trivalent citric ion in preventing the crystallisation of supersaturated solutions has recently been noticed by the writer.

Similar effects appear to occur in the formation of glass. The production of opal glass is due to the separation of microscopic globules or spherites, which is the form in which crystals very frequently occur in colloidal media. Opal glasses produced with phosphates "strike" generally at higher temperatures than those made with fluorides. This means that crystallisation of the insoluble component takes place more readily in the presence of the trivalent anion. The opposite effect is shown by the powerful action of trivalent aluminium, and the still greater influence of tetravalent titanium, tin, thorium, and zirconium, in hindering devitrification due to subsequent growth of visible crystals in the glass.

---

* Bradford, *Phil. Mag.*, 1919, **38**, 697.

Another instance is afforded by the effect of alkalis on the development of colour in glass. If three similar moderately soft glasses be made containing, respectively, potash, soda, and lithia as the alkalis present in chemically equivalent proportions, the same amount of nickel oxide being contained in each glass, marked difference in the colours produced is observed. The potash glass is a fine, deep violet, the soda glass almost brown, and the lithia glass yellowish-brown with less strength of colour altogether. The effect of the alkalis is in the well-known order quoted above.

Such considerations are sufficient to suggest that the application of von Weimarn's theory would provide a working basis for the science of glass technology which might lead to useful results.

THE SCIENCE MUSEUM,
SOUTH KENSINGTON,
LONDON, S.W. 7.

ABSTRACTS AND REVIEWS

I.—Glass-making Materials.

1. The Deterioration of Lime on Keeping. S. A. Woodhead (*Analyst*, 1918, **43**, 161).—A summary of the author's tests and results is as follows:—

(1) Powdered lime was placed on the floor of a dry shed in such a way as to expose a large surface. Every day during sixty-four days it was turned over with a spade, and re-spread to cover the same floor space. At the end of sixty-four days the percentage of free lime had decreased from 69·1 to 39·5, the loss being equivalent to 43 per cent. of the free lime.

(2) Powdered lime was dumped in a heap outside and exposed to the weather for four months without being touched. Analyses showed the following percentages of free lime:—

At commencement of test	69·1
After four months' exposure:—	
Crust of heap	0·0
Interior of heap	66·9
Average of mixed crust and interior	60·8

The average deterioration of the sample was equal to 12 per cent. of the free lime. After four months the crust had been changed completely to calcium carbonate.

(3) A sample of lump lime was placed in a bag and left outside protected from rain. In four months the percentage of free lime (mixed sample) decreased from 81·2 to 50·3, equal to a loss of 38 per cent. of the free lime.

(4) A sample of lump lime was dumped outside and exposed to the weather. In four months the free lime (mixed sample) decreased from 81·2 per cent. to 38·8 per cent., equal to a loss of 52 per cent. of the free lime.

From the above results it appears that in order to store lime to the best advantage it should be heaped in a powdered condition.

J. D. C.

2. The Prospects of Founding a Potash Industry in this Country. Kenneth M. Chance (*J. Soc. Chem. Ind.*, 1918, **37**, 222T).—The author mentioned three industries in which potash may be recovered as a by-product, namely, the blast-furnace industry, the manufacture of cement, and the washing of raw wool. The recovery of potash in a gas-cleaning plant for a blast furnace had the enormous advantages over all other native sources of supply in that the value of the main product of the plant, namely, the clean gas, was in itself sufficiently great to provide remuneration for the capital outlay involved in erecting and operating the plant, and also the main items of cost (raw material, labour, and fuel) in volatilising potash from an ore in which it is present in insoluble form are reckoned and incurred as items of cost in the original manufacture (that is, of the pig iron).

In the autumn of 1914, the Halberg-Beth plant installed at the works of the North Lincolnshire Iron Co., Ltd., for the purpose of cleaning their blast-furnace gases came into operation. A sample of the dust recovered was found to contain considerable quantities of potash and of cyanide.

An arrangement was made with the British Cyanides Co. at Oldbury for a joint investigation into the possibilities of working up the dust into commercial products. Many working difficulties were encountered, and considerable research was needed both at the blast furnaces and at the Oldbury works. At the furnaces the gases had been water-cooled. Soluble potash salts were thereby carried away and lost. To avoid this, a Green's economiser was installed. (This plant was really too costly for the purpose; one of the greatest difficulties is that there is at present no efficient plant for the dry cleaning of the gases.)

Frequently much of the potash remained associated with the slag. A considerable amount of work was done in ascertaining the effect of the temperature of the furnace on the quantity of potash volatilised. A higher temperature usually meant more potash in the dust, but running the furnaces with periods of higher temperature was not satisfactory.

Whilst carrying out these investigations, it was noted that the amount of volatile chloride in the gas remained constant, and from this it was inferred that the chlorides in the furnace charge were practically constant and were all volatilised. If, then, additional chlorides were artificially fed into the furnace, they should combine with those bases having the most volatile chlorides. Potassium chloride, being the most readily volatilised, should ensure that all the potash was found in the gas as chloride. Salt was therefore added to the furnace in sufficient quantity to volatilise the whole of the potash, and the amount of potash in the gas was thereby increased from about 60 lb. to upwards of 200 lb. per million cubic feet of gas.

The use of salt has been repeated in several blast furnaces in other parts of the country, and in every case the quantity of potash volatilised has been considerably increased. The use of salt appears to have no adverse results on the manufacture of pig iron. Sufficient potash for the founding of an industry can then be obtained.

By the use of suitable quantities of salt coupled with efficient gas-cleaning plants at the blast furnaces, it should be possible to meet the potash requirements of this country, and at a price which, on a pre-war basis of cost, is less than the lowest figure at which German potassium chloride has ever yet been marketed in this country (namely, £8 per ton).

Arrangements have been made for the manufacture of caustic potash in bulk from the chloride by electrolysis, whilst the salts being produced include potassium carbonate, potassium bicarbonate, potassium ferricyanide, and potassium permanganate.

During a discussion of the paper, the question was raised as to whether calcium chloride (a cheap waste product) might not be found as efficient as salt.

In regard to potash from cement kilns, there was ample evidence to show that by the use of salt in the cement kiln, either in the crystalline form or as sea-water, potash was volatilised. The greatest difficulty was the construction of cheap and efficient plant for extracting the potash from the gas. According to one authority, a combination of electrical precipitation and the collection of the dust in the form of a slurry had been found successful The gas from a cement kiln had no value beyond its potash contents, and therefore, unless some counter-balancing advantage could be discovered and utilised, the cost of recovering potash must always be greater from a cement kiln than from a blast furnace.

If raw wool received a preliminary washing in cold water, potash may be recovered from it as carbonate in a solution which was contaminated with a small proportion of the natural fats of the wool. If certain physical difficulties of concentration could be overcome there was no doubt that potassium carbonate of great purity could be recovered and the fats rendered of value in the form of gas and oils. A. M. J.

3. The Alsace Potash Deposits and their Economic Significance in Relation to Terms of Peace. PAUL KESTNER (*J. Soc. Chem. Ind.*, 1918, **37**, 291T).—The paper first points out that Alsace-Lorraine is in reality the key to the industrial and economic supremacy of Germany, as it contains the potash deposit of Alsace and the iron ore deposit of Lorraine. The loss of the latter would render Germany dependent on foreign countries for more than 80 per cent. of her iron ore consumption of 30 million tons per annum.

The author compared the yield per hectare of the principal crops (wheat, rye, oats, barley, potatoes, sugar-beet) of Germany and of France for the year 1913–1914. In each case the yield was greater in Germany, in spite of the fact that the soils of Germany are for the most part ancient sand deserts, whilst the soils of France are most favoured by nature. This is accounted for by the fact that Germany has the potash monopoly, and uses more potash than any other country in agriculture. During the war, by still further increasing the amount of potash used, the Germans have been able to increase their crops and to some extent to discount the blockade.

A summary was also given of the sources from which the world's consumption of potash can be supplied, namely:—

North Germany.—About 1850 potash was discovered in the rock-salt mines of Stassfurt. The workings now extend over a wide area in Brunswick, Hanover, Mecklenburg, and Thuringia. In 1907, thirty-nine companies united into one huge syndicate, the famous Kali Syndikat, which to-day holds practically a potash monopoly. As soon as the Alsace deposits were discovered they came under the control of the Syndicate, and so completed the formidable economic weapon wielded by Germany. With rare exceptions, the salts from the North German basin contain a fairly large proportion of magnesia, and need refining before they can be used even in agriculture.

Galician Deposits.—These beds do not seem to be able to provide even for Austria-Hungary alone, since in 1913 that country imported 21,000 tons of potash from Germany.

Spanish Deposit.—Potash was discovered shortly before the war at Suria in Catalonia, a district where rock-salt mines were already worked. The deposit extends over a considerable area, but is not continuous in the beds as is the case in Alsace; moreover, it appears that the working is rendered difficult because the beds, instead of being horizontal, as in Alsace, are steeply inclined. The deposit comprises both carnallite and sylvinite, the carnallite, which is the more plentiful, containing at least 12 per cent. of K_2O.

United States deposits are not potash mines, but salt lakes situated in the Rockies, in the States of Nebraska, Utah, and California. The reserves are considerable.

Italian deposit at Erythria is of a recent lacustrine formation. The reserves are inconsiderable, but, on the other hand, the deposit is important on account of the richness of the salt, which contains 80 per cent. of KCl.

In *Tunis,* to the south of Gabes, a salt lake of 15,000 hectares has been worked since 1915 primarily for bromine, though also for potash.

In *Chile,* lakes containing deposits of potassium chloride have been found; there is a reserve estimated at 2,000,000 tons, which has a content of from 3 to 12 per cent. of chloride.

There are also deposits in Peru, in Russia, in Morocco, and in the province of Overyssel in Holland which have not hitherto been developed.

There are also natural deposits of potassium nitrate in India and in Chile.

Salt marshes, notably those in the Rhone delta, supply mother liquors from which potassium chloride can be extracted.

Potash may also be recovered from the dust from blast furnaces and cement kilns.

The *Alsace* potash beds are situated in the south of the province, in the plain, bounded on the south by the Jura, on the west by the Vosges, and on the east by the Rhine. Recent borings have shown that secondary beds of the same formation are to be found beyond the Rhine. The deposits consist of two beds situated below a deposit of rock-salt. The beds are formed for the most part of pure sylvinite, the upper bed having an average content of 35 per cent. of potassium chloride, and the lower one of 30 per cent. The layers are nearly horizontal and are not subject to the infiltration of water. The whole deposit represents more than 300 millions of tons; hence one may reckon that it would suffice for the world's consumption for many years.

The purity of the salt greatly surpasses that of all other known deposits of importance; refining is unnecessary for the salt intended for agriculture. The potash was detected by prospectors looking for coal in 1904; working began in the first shaft in 1910.

The German Potash Syndicate has taken care to limit the working of the Alsace deposit, and only allowed an output of 5 per cent. of the total German output. A. M. J.

4. Potash (from Lakes) in Nebraska. J. M. LLITERAS (*Chem. and Met. Eng.*, 1918, **19**, 633).—It has been proved by the continuous pumping of certain lakes that the potash supply of Western Nebraska is not inexhaustible, as the density of the water falls after a certain length of time. If the lakes, however, are allowed to "rest," the density of the water increases, and in rare cases may attain the original value. Nebraska is now producing about 450 tons of salts daily with an average potash content of 25 per cent. K_2O. C. M. M.

5. Potash Salts in Hungary. F. VON KONEK-NORWALL (*Chem. Zeit.*, 1918, **42**, 365).—Large quantities of alunite are stated to occur in Northern Hungary, from which potassium sulphate may be recovered by roasting at a red heat until all the aluminium sulphate has been decomposed and sulphuric acid fumes are no longer evolved. The residue, in the form of a white powder, consists of potassium sulphate (14—15 per cent.), alumina, and silica, from which with water the potassium sulphate may be separated. C. M. M.

6. Potassium Salts. (Brit. Pat. No. **111845**). F. W. HUBER and F. F. REATH (November 14th, 1917, No. 16741. Convention date, December 2nd, 1916. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—Potassiferous flue dust, such as that obtained by electric separation from the flue gases of cement kilns, is treated with water and the solution separated from the insoluble residue, all the operations being effected at a temperature not lower than about 85°, preferably nearly 100°, so as to avoid the formation of the insoluble double salt

$$CaSO_4,K_2SO_4,H_2O.$$

Preferably the quantities are so chosen as to give a solution containing about 4—5 per cent. K_2O. H. G. C.

7. Sand Washing. (Brit. Pat. No. **111061**). J. Southall June 26th, 1917, No. 9147).—A sand-washer comprises a trough *A* with an undulating bottom, in each section of which is mounted a rotary system of paddles *C* and stirrers *D*, which pass the sand through the apparatus towards the discharge end *K* in the opposite direction to a stream of water. At the end *K*, the washed sand is raised by revolving hollow arms *R* to a discharge cone *L*. The dirty water overflows at an outlet *U*. The bearings of the shafts *F*, *N* are arranged above the water-level. H. G. C.

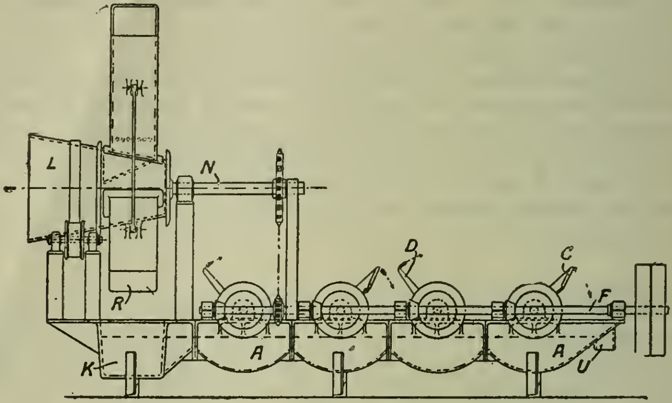


Fig. 1.

8. Manufacture of Cryolite from Sodium Bisulphate, Silica, and Fluorspar. Chem. Fabr. Goldschmieden H. Bergius & Co., Goldschmieden (Ger. Pat. 307525, 23/1/17).—According to the process described, silicon fluoride, produced by decomposition at red heat of fluorspar and silica by means of sodium bisulphate, is absorbed by solid hydrated sodium sulphate. After separation of sulphuric acid or sodium bisulphate, the sodium silicofluoride is decomposed by fusing it with crystalline sodium carbonate in the proportion of 1 mol. of sodium silicofluoride to 4 mols. of sodium carbonate, with the production of sodium fluoride, sodium bicarbonate, and silica. The silica is filtered off, and cryolite precipitated by addition of sodium aluminate to the solution. The reactions which take place may be represented by the following equations:—

$$2CaF_2 + 4NaHSO_4 + SiO_2 = SiF_4 + 2Na_2SO_4 + 2CaSO_4 + 2H_2O.$$
$$3SiF_4 + 2Na_2SO_4 + 2H_2O = SiO_2 + 2H_2SO_4 + 2Na_2SiF_6.$$
$$Na_2SiF_6 + 4Na_2CO_3 + 10H_2O = 6NaF + SiO_2 + 4NaHCO_3 + 8H_2O.$$
$$6NaF + 4NaHCO_3 + NaAlO_2 = (NaF)_3AlF_3 + 4Na_2CO_3 + 2H_2O.$$

C. M. M.

9. The "Swelling" of Silica. Th. Hebbeler (*Chem.-Zeit.*, 1918, **42**, 593).—The author found that if 2 grams of kieselguhr were shaken with water in a 250 c.c. graduated cylinder and then allowed to settle for twenty-four hours, the siliceous sediment occupied a volume of 8 to 18 c.c. If the clear water were then drawn off and replaced by a solution of calcium hydroxide, which in turn was drawn off and a fresh quantity added every day, the volume of the sediment increased gradually until, after fourteen days, it measured 68 to 196 c.c., according to the grade of kieselguhr employed.

This increase in volume was not due to increase in the size of the silica skeletons, but to the separation of calcium hydroxide occluded in the mass. The greater part of the precipitated matter could be removed by extraction with water, and the small portion which was precipitated as carbonate could be removed by water containing carbon dioxide. The volume of the kieselguhr then diminished to that observed originally.

The phenomenon appeared to be purely physical, with no formation of calcium silicate. J. D. C.

II.—Glass: Manufacture and Properties.

10. Barium Carbonate in Glass Manufacture. (*Sprechsaal*, 1905, **38**, 55).—The use of barium carbonate in glass manufacture makes the glass more readily fusible, more refracting, and denser. The following batches suitable for pressed glass are quoted:

	I.	II.
Sand	100 kg.	90 kg.
Potash	10	15
Soda	25	13
Barium carbonate	25	10
Saltpetre	6	—
Limespar	5	4
Nickel oxide (decoloriser)	—	(2—3) gr.

J. R. C.

11. Yellow Tank Glass. (*Sprechsaal*, 1905, **38**, 42).—The following batch is recommended for the production of yellow glass in a tank furnace:

Sand (with 2 per cent. iron oxide content)	100
Chalk, powdered	45
Salt-cake, 96 per cent. powdered	28—29
Coke, finely powdered	1·5
Manganese, powdered	5·5—6

The batch is said to melt in any good tank furnace, whatever the nature of the firing. By raising the manganese content and the addition of small quantities of iron oxide, the glass can be made darker, until a reddish-brown colour is obtained. J. R. C.

12. The Raw Materials for Plate-glass Works. (*Sprechsaal*, 1904, **37**, 454).—The importance of using pure raw materials if it is desired to obtain a good glass is emphasised. With reference to the form in which the alkali is to be added, it is remarked that, when soda is used, the glass melts much easier and more rapidly than when the salt-cake is employed and the attack on the pot is less. The use of salt-cake also necessitates the addition of coke or coal. This must also be pure carbon, and should be finely powdered. The addition of a small quantity of arsenic helps the batch to melt and gives the glass a clear, bright appearance. The two following batches were recommended as giving good clear glasses:

	I.	II.
Sand	100 kg.	100 kg.
Lime	22 ,,	27 ,,
Soda	40 ,,	—
Salt-cake	—	48 ,,
Coke (powdered)	—	3 ,,

J. R. C.

13. The Difference between Burning-off and Skimming-off Glass Gall. (*Sprechsaal*, 1904, **37**, 1757).—According to the author, the glass gall usually consists of sodium sulphate, which can be got rid of in two ways: either by skimming or addition of carbon to reduce it. The latter method can be carried out by running the furnace with a smoky flame. The effect of the two methods is different, for, in the latter case, the carbon reduces the sodium sulphate to sodium oxide, sulphur dioxide, and carbon dioxide. Thus for every 100 parts of gall there remain in the glass, when it is burnt off, 43 parts of sodium oxide, which would be removed if the gall were skimmed off. The resulting glass has thus a higher alkali content when the second method is adopted.
J. R. C.

14. Gall-bubbles. H. Knoblauch (*Sprechsaal*, 1904, **37**, 3).—
—In the author's view, gall-bubbles are hollow spaces in glass filled with glass-gall, which probably consists of sodium sulphate. They arise, he believes, in the majority of cases, from the furnace temperature being too low. They can, however, be produced, even when the furnace is hot, being then due to lack of carbon. The addition of carbon or the maintenance of a reducing flame will remedy the trouble in this case. J. R. C.

15. Faulty Bottles. (*Sprechsaal*, 1904, **37**, 717, 756, 792).—The errors which may produce faulty bottles are divided into those due to the glass itself, to the annealing, to the workmanship, and to the decoration. In the first group are included such faults as cords, waves, seeds, and stones. The causes of these faults are enumerated. Bottles well annealed are much more durable than those which are not. Well-annealed bottles will stand a pressure of 30 atmospheres, when similar, unannealed bottles collapse at a pressure of 5 atmospheres. Under this heading is also included the bloom which is often produced in the lehr. It is stated that this can be obviated by keeping the flames away from the glass. Under the heading of errors in workmanship are mentioned those due to the gathering of the incorrect amount of glass and to the bulb on the iron being the wrong shape before the glass is blown in the mould. If the glass is too hot when blown, the bulb may be good and a bad article still produced, as the walls may sink in the mould. A further source of error occurs when the neck of the bottle is made. The neck must be as hot as the additional glass applied or the bottle is liable to crack at this point.

J. R. C.

16. The Lack of Resisting Power of Bottle Glass. Heningk-Lorenz (*Sprechsaal*, 1905, **38**, 961).—A glass which is recommended as acid resisting to a sufficient degree for ordinary purposes is:

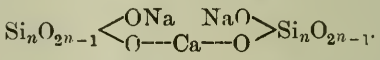
Silica	64·63	per cent.
Alumina Iron	7·77	,,
Lime	16·19	,,
Soda Potash	9·33	,,

J. R. C.

17. Moulds for Hollow Ware. W. Grull (*Sprechsaal*, 1905, **38**, 639).—In view of the cost of iron moulds, such as are usually employed, the author discusses their replacement by wooden ones. The disadvantage of the latter, of course, is that they change shape through burning away. It was found, however, that if "very light" glass is used, about 1,500 articles could be made before the mould had to be discarded. With "fairly heavy" glass and "heavy" glass, the numbers were 800 and 500 respectively. A disadvantage of the iron mould is that, being a good conductor, it quickly chills the glass, with the tendency to produce fine cracks on the surface, whilst it also rusts. To prevent the rust, Bocuze nickel-plated the inside of the mould, and thereby, in addition to eliminating the rust, obtained a polished surface in which to blow the glass. A wooden mould gives a better surface, and this may be advantageous for pressed ware. A mould made from lignite was tested and found to disintegrate as rapidly as a wooden one.

The ideal mould should be made of some substance having a low conductivity, not easily destroyed by the heat of the glass, and capable of producing a velvety surface. The amorphous modifications of coal were suggested for the purpose, namely, graphite, coke, and charcoal. In this connection, mention was made of an English patent (1869) which endeavoured to substitute a coke mould for an iron one. The coke was bound together with pitch and afterwards with tar, but these binding materials were the cause of failure. The author tried gypsum and kaolin in varying quantities with tar, but was not successful in obtaining a good medium. J. R. C.

18. Glass, its Chemical Constitution and Properties. (*Sprechsaal*, 1905, **38**, 482).—In nearly every glass silica is present in combination with two oxides, one of which is monovalent and the other divalent. There are other types, as, for example, phosphate glasses and Peligot's glass without alkali, in which barium oxide and lime are combined with silica; and also there may be more complex glass, as when lead oxide is partly replaced by baryta, giving a tri-basic glass. Dumas held that glass is a real salt, and always alkaline, and that it is always either a definite tri-silicate compound or a mixture of such. This is now doubtful, and it is probable that it is not a simple compound, but an indefinite mixture of definite silicates. Weber has put forward a formula for glass, $xM'_2O,yM''O,3(x/y^2+y)SiO_2$. Zulkowski, studying glass from a purely chemical point of view, arrived at the conclusion that a meta-silicate is usually formed, namely, $SiO(OM)_2$. An ortho-silicate can only be produced when alkali is greatly in excess and a very high temperature, higher than the usual glass furnace temperature, is attained. When, on the other hand, silica is in excess, a silicate of the type $Si_nO_{2n-1}(OH)_2$ arises. A practical glass must be di-basic, and Mylius and Förster are of the opinion that it is not a mixture of single silicates, but a double silicate of the form



$$Si_nO_{2n-1}{<}\begin{matrix}ONa & NaO\\ O{-}{-}{-}Ca{-}{-}{-}O\end{matrix}{>}Si_nO_{2n-1}.$$

They hold that a homogeneous glass can only be formed under the following conditions: (1) The mutual proportions of the bases must correspond with the formula $6SiO_2.M''O,M'_2O$. (2) In every series of $M''O$ or M'_2O there must be only one base present (except for Na_2O and K_2O). (3) The more homogeneous a glass is, the more resisting it is.

In practice the first two rules are not adhered to. The presence of poly-meta-silicates corresponding with aluminates is probable, and the same may be said of borates and phosphates. The modern theory of glass is that it is a mixture of silicates, which, when molten, are in a state of mutual solution. When cooling takes place, this condition persists, unless it is so slow that crystals are formed, when devitrification sets in. The crystals so formed have a different composition from the glass. Appert and Henrivaux found that *wollastonite* crystallises out of soda and potash glasses, and *augite* from magnesia- and iron-containing glasses.

J. R. C.

19. Iron in the Furnace Atmosphere as a Source of Colour in Optical Glass. E. W. WASHBURN (*J. Amer. Cer. Soc.*, 1918, **1**, 637).—The observation that an optical glass, melted in an electric furnace, yielded a colourless product, whereas the same batch melted in a similar pot, but in a gas-fired furnace, invariably yielded a green glass, led to an investigation of the atmosphere of the furnace as a possible source of contamination with iron.

A silica tube was inserted through the wall of the furnace so that the end of the tube was immediately above the pot of melted glass. At the maximum temperature attained by the furnace, and just previous to stirring, a stream of gas from the interior of the furnace was drawn through a wash-bottle containing sulphuric acid. After a period of two hours the experiment was concluded, the interior of the silica tube washed with some of the acid, and the acid then examined for iron. Distinct positive results were obtained.

The colour of the glass in the pot after several hours' stirring was inferior to that previous to the stirring, this being due, in the author's opinion, to the iron taken up from the furnace atmosphere being thoroughly mixed throughout the glass during the stirring process. The iron present in the atmosphere of the furnace appeared to be in the form of ferric oxide, but whether as vapour or fine dust was not definitely ascertained. Further experiments to measure the vapour pressure of ferric oxide at high temperatures might settle this point. The obvious sources from which the iron might emanate were (1) the iron burners, which were covered with a coating of oxide on the ends in the interior of the furnace, and (2) the iron content of the fire-brick furnace lining. On using clay burners, and coating the interior lining of the furnace with kaolin, a distinct improvement in the quality of the glass was observed. The kaolin lining gradually acquired a red tint, either by the absorption of iron from the fire-clay brick behind it or from iron in the furnace atmosphere.

The author recommends (1) lining the interior of the furnace with a course of kaolin bricks, and (2) water-cooling any metallic iron object necessary in the interior of the furnace. J. H. D.

20. The Identification of "Stones" in Glass. N. L. BOWEN (*J. Amer. Cer. Soc.*, 1918, **1**, 594).—"Stones" in glass include all foreign particles of a non-vitreous nature. They may be due to a variety of causes, and are classified according to their origin as (1) pot stones, (2) batch stones, (3) crown drops, and (4) devitrification stones. A proper identification of the type and source of the stones leads to the surest and speediest elimination of them. Chemical analysis is sometimes used, but is unsatisfactory, as the "stones" are frequently very small, and it is impossible to free them entirely from the enclosing glass. Microscopic examination affords a surer and more satisfactory method of investigation, as this renders possible a determination of the refractive indices and other distinctive optical properties, and is particularly useful in the examination of fine materials intimately intergrown.

"Pot stones" are occasionally comparatively large, but usually quite small. They are always white, even when formed from dark burning clays. They are formed of crystals of *sillimanite* (Al_2O_3,SiO_2) with a little interstitial glass. *Sillimanite* is a universal constituent of "pot stones," and is never found in stones of other origin.

Lack of uniformity in the pot material is a more serious cause of "pot stones" than is the actual solution of the pot material in the glass, since it may give rise to local pitting and the casting of highly resistant stones. If "pot stones" are a frequent source of trouble, the remedy is to be sought for in (1) more careful arching of the pots, (2) varying the batch to render it less corrosive, (3) melting at a lower temperature, and (4) altering the composition of the pot clay.

"Batch stones." The only normal batch constituent liable to remain unassimilated in the glass is the sand. Batch stones therefore usually consist entirely of silica. If the size of the grain be large, there may be a core of unchanged quartz surrounded by a layer of *cristobalite* or *tridymite*. If the grain be small, it may be entirely converted into *tridymite* or *cristobalite*, without any interstitial glass. A batch stone is usually surrounded by an aura of glass of low refractive index, and frequently has a "tail" of similar material. The remedy for batch stones may be (1) to soften the batch, (2) to melt at a higher temperature, (3) to use finer sand, or (4) to pay attention to the more careful mixing of the batch ingredients.

"Crown drops" are caused by the gradual corrosion of the crown bricks by the vapours given off from the batch, and the subsequent falling of drops of fused material, frequently carrying particles of the crown bricks with them, into the glass. In the case of a silica crown, such particles usually consist of rather large crystals of *tridymite*, in contradistinction to the very fine-grained crystals of *cristobalite* usually indicative of batch stones.

"Devitrification stones." When some portion of the glass separates out from the clear metal in the form of crystals, "devitrification" is said to have taken place. This may occur in two forms. The crystals may be large, easily recognisable with the naked eye, and disseminated in a glass otherwise clear, or the crystals may be so small and close together as to give an opaque appearance to the glass as a whole. Both phenomena are essentially the same, although the second type would scarcely be regarded as due to the formation of "stones."

A common form of devitrification is that in which spherulites are formed in the glass. These appear to be entirely crystalline, but are really composed of crystal fibres radiating from a core, the interstitial fibres being filled with glass. If the crystals are silica, this is usually in the form of *tridymite*, and the interstitial glass has a higher refractive index than the glass surrounding the spherulite. *Wollastonite* (calcium silicate) also frequently separates from the glass in the form of spherulites. These consist of prismatic fibres of *wollastonite* with interstitial glass containing minute crystals of *cristobalite*. From special batches, barium silicate ($BaSi_2O_5$) or lead silicate ($PbSiO_3$) may separate.

The separation of these "devitrification stones" usually means that the material of which they are formed is in excess in the batch. If it is not possible to reduce the amount, owing to the corresponding effect on the properties of the glass, recourse must be had to variation in the heat treatment in order to reduce the quantity of such stones to a minimum. The optical properties of the crystals usually found in glass are summarised briefly as follows:—*Sillimanite* (Al_2SiO_5): refractive indices, $\gamma = 1{\cdot}681$ and α 1·660. The refraction is higher than that of all glasses except the very heavy lead glasses. Other refractive indices are:—*Quartz*, 1·553 and 1·544; *tridymite*, 1·469—1·473; *cristobalite*, 1·484—1·487; *barium disilicate*, 1·617—1·598; *wollastonite*, 1·633—1·620.

J. H. D.

21. The Condition of Arsenic in Glass and its Rôle in Glass-Making. E. T. Allen and E. G. Zies (*J. Amer. Cer. Soc.*, 1918, **1**, 787).—The authors have investigated the amount and character of the arsenic retained in optical and plate glasses, and find that the major part exists in the pentavalent state, but that a portion exists in the trivalent state. The amount of arsenic present in the glass as As_2O_3 and As_2O_5, respectively, was determined, and the amount that should be present was calculated from the batch mixture on the assumption that only moisture, CO_2, and oxygen (from KNO_3) were lost.

The results showed that in the case of four glasses in which the batch contained nitre, the loss of arsenic varied from 11 to 21 per cent., and of the arsenic retained in the glass about 86 per cent. in three cases and more than 90 per cent. in the fourth case was in the pentavalent condition. In the case in which the batch did not contain nitre, 33 per cent. of the arsenic was lost in the furnace, and the amount of As_2O_5 found in the glass was twice that of the As_2O_3.

The authors favour the opinion that the arsenic is oxidised to the pentavalent condition at the lower temperatures, and the product is dissociated at high temperatures, As_2O_3, the oxygen escaping, and thus assisting in the fining of the glass. J. H. D.

22. Selenium and the Nature of the Decolorising Process. G. Rauter (*Sprechsaal*, 1904, **37**, 598).—The principle of all decolorisers is that when added to the batch they produce a bluish-violet colour, which is complementary to that due to iron. As a result, the glass appears to be decolorised, but is actually coloured a faint grey. A decoloriser is the more effective the weaker this grey tint is. Cobalt oxide and nickel oxide can be used, exceedingly little of them being required to counteract the yellowish-brown iron colour. The action of manganese is uncertain; this is because it performs a double function. It oxidises the iron to give a yellow colour and then neutralises it. Selenium, on the other hand, is a strong reducing agent, and can be used to colour a glass red. It would thus be thought that the action of the selenium would be to reduce the iron to a lower oxide and then superpose its red on the green thus produced. However, the glass is usually green, as the usual furnace atmosphere is reducing; therefore an investigation of the properties of selenium was undertaken with the view of elucidating its action. The conclusion was drawn that glass is coloured red by selenium on account of numerous reflections at the surfaces of minute selenium particles which are in suspension in the glass. If only a small amount of selenium is added, the red is not strong, but there are still many reflections. The green light from an iron-containing molecule is not reflected and does not emerge from the glass, which is thus decolorised. J. R. C.

23. Decolorising Media and their Action. (*Sprechsaal*, 1905, **38**, 1331).—On account of the high melting point of nickel oxide, its action takes place at the end of the melt. Special care must be taken to get it pure, as it may contain cobalt. The quantity required is given as 2—5 grams of nickel oxide to 100 kg. of sand.

Cobalt oxide must be used with care, as a very little too much will colour the glass blue. In ordinary circumstances, half a gram is enough for every 100 kg. of sand in the batch.

Manganese dioxide gives a different colour when used with a potash batch from that obtained with a soda batch. Much more is required to decolorise an ordinary glass than with nickel or cobalt oxides, 250 to 300 grams being necessary for every 100 kg. of sand. Glass decolorised by manganese turns violet with prolonged exposure to sunlight.

As a rule, about 220 grams of antimony oxide will be enough for 100 kg. of sand in the batch. It is not recommended, however, as it is liable to attack the pot. The uncertainty about the action of selenium, which may colour the glass red, militates against its use. Arsenic is of more value as a means of clearing the glass than as a decoloriser. J. R. C.

24. Strengthened Glass (Brit. Pat. No. **111539**). S. Goldreich, C. A. McKerrow, and Splinterless Anti-Mist Glass Syndicate (December 2nd, 1916, No. 17346).—In the manufacture of strengthened glass comprising two sheets of glass and an interposed sheet of celluloid, the celluloid is treated, not with a solvent of celluloid, but with a softener thereof, such as industrial spirit, and is caused to adhere to the glass by the simultaneous action of heat and pressure. Specification 1790/10 is referred to.

H. G. C.

25. Strength Tests of Plain and Protective Sheet Glass. T. L. Sorey (*J. Amer. Cer. Soc.*, 1918, **1**, 801).—A study of the effect of a thin coating of celluloid on the mechanical properties of sheet glass.

The tests imposed were of three types, namely, (1) firing tests, (2) impact tests, and (3) cross-bend tests.

For the firing tests, bullets were fired from a regulation rifle at a distance of 50 feet. For the impact tests the sheets were supported in a frame, and struck by a $1\frac{1}{4}$ lb. steel ball at the end of a stiff wire arm, 24 inches long, forming a pendulum. The latter was allowed to swing through 5°, then 10°, and so on, the angle of swing being increased until the plate fractured.

For the cross-bend tests, strips of glass 12 in. × 2 in. were placed upon supports 10 in. apart, and increasing pressure applied to the middle of the strip until fracture occurred.

The results of the tests showed that:—

(1) In both impact and cross-bend tests, blown window glass is stronger than plate glass.

(2) Whilst the energy of impact necessary to produce fracture increased with the thickness of the glass, the amount of cracking occurring at the time of initial fracture also increased.

(3) The force of the blow required to crack a piece of glass is not materially increased by the celluloid coating, but the shattered glass remains in place.

(4) In the cross-bend tests, the protective glass is about 15 per cent. weaker than plain glass when the celluloid-coated side is in compression, but about 40 per cent. stronger when the celluloid-coated side is in tension. J. H. D.

26. The Effect of certain Impurities in causing Milkiness in Optical Glass. C. N. Fenner and J. B. Ferguson (*J. Amer. Cer. Soc.*, 1918, **1**, 468).—In the manufacture of optical glass by the Bausch and Lomb Optical Company, a matter which gave considerable difficulty for a time was the occasional production of pots of milky or opalescent glass. A light flint which had a PbO content of about 33·5 per cent. and the refractive index of which was about 1·572 was the type of glass in which the phenomenon most frequently occurred. The evidence indicated that the source of the trouble lay in the sulphate and chloride content of the Russian potash which replaced the German product.

Certain considerations rather obscured matters

(1) There seemed no direct connection between the amount of sulphate or chloride in the potash and the tendency of the glass to become milky.

(2) Experimental melts were made in small pots, and various amounts of sulphate and chloride were added to the batches, and again there seemed no relation between milkiness and the amount of sulphate or chloride added.

(3) During a laboratory study of the ternary system CaO–MgO–SiO_2, a similar milkiness had been obtained, and it had been

possible to detect multitudes of minute crystals of SiO_2 with the microscope.

More trustworthy methods of temperature control were installed, and it was found that the formation of the pots of milky glass ceased when the pots were held at 1400° or a little higher for a period of about thirty-six hours. Later, when it seemed desirable to cut down the length of time the pots remained in the furnace, pots of milky glass again began to appear, although potash containing only 0·3 per cent. SO_3 as a maximum was used in the batch. The trouble was reduced when the length of time of stirring was increased.

Apparently the elimination of the last traces of SO_3 and Cl from a glass is favoured by a high temperature and prolonged time, and also by agitation of the melt which accompanies stirring.

If a glass which was milky or was likely to become milky was heated to 1100—1150°, the milkiness disappeared, but glass so treated developed numerous bubbles. Analysis showed that a very milky glass contained 0·14 per cent. SO_3. After being cleared up by heat treatment, the same glass contained 0·06 per cent. of SO_3. It is doubtful whether the minute particles to which the milkiness is due are themselves composed of sulphates or chlorides; it is more probable that sulphate or chloride impurities behave as catalytic agents, causing the separation of clouds of minute crystals of crystobalite. With the best microscopic magnification, it is barely possible to discern discrete particles of foreign matter, as they are so minute as to be of similar order of magnitude to the wave-length of light. The bluish colour of opalescence shows that they produce a scattering of light rays. The devitrifying effect of sulphate and chloride must also vary with the composition of the glass, for an analysis of a glass for searchlight mirrors manufactured in England gave 0·74 per cent. of SO_3, and it showed no tendency to devitrify.

The Russian potash could also be employed without detriment in the manufacture of a light crown glass. A. M. J.

27. The Effect of certain Impurities in causing Milkiness in Optical Glass. F. GELSTHARP (*J. Amer. Cer. Soc.*, 1918, **1**, 559).—A criticism of the paper by Fenner and Ferguson. The Pittsburgh Plate Glass Co. had been very successful in producing several types of optical glass. In early work, an occasional pot of milky glass was obtained, the glasses in which the opalescence was produced being a boro-silicate crown (refractive index 1·522) and a dense flint (refractive index 1·616). Impure potassium carbonate was not the cause of the opalescence, as pure nitrate was used to supply the necessary potash.

The optical glass referred to by Fenner and Ferguson and the two mentioned above have a high molecular content of silica, and therefore approach supersaturated solutions. In the author's view, if for some reason the alkali content is lower than intended, milkiness may easily result. Thus,

(1) KCl and K_2SO_4 in Russian potash may be responsible for the deficiency of K_2O in glass.

(2) Variable composition of Russian potash would mean variable alkali.

(3) A considerable amount of alkali volatilises, and the amount varies with furnace conditions.

Further experiment was therefore necessary before accepting the statement that SO_3 and Cl in some optical glasses will cause milkiness. It is probable that the presence of salts in solution in glasses which contain a high proportion of silica (approaching a supersaturated solution) will tend to cause such glasses to turn milky more readily on slow heating or cooling, although the writer had never found that the presence of SO_3, Cl, or F in soda-lime glass (in amounts up to 0·6 per cent. of each) caused opalescence to the slightest extent so long as the ratio of alkali to silica was below the limit at which opalescence occurs when SO_3, Cl, or F were absent. A. M. J.

28. The Effect of certain Impurities in causing Milkiness in Optical Glass. C. N. Fenner and J. S. Ferguson (*J. Amer. Cer. Soc.*, 1918, **1**, 561).—A reply to the criticisms of Gelstharp. The authors consider there is no likelihood of the calculated alkali in their glasses being low. As there was no reason to suppose that the K_2O content of K_2SO_4 in a lead–alkali–silica mixture was more volatile than the K_2O of K_2CO_3, the equivalent K_2CO_3 for the K_2SO_4 of the potash was calculated, and that amount used; also, as KCl is volatile, it was considered safest to assume that it all escaped, and additional potash was allowed for this. The authors hesitate to believe that glasses are in such a critical region that the addition of a little silica will throw them into a supersaturated condition. A set of laboratory experiments gave evidence on this. A glass which became milky on reheating was used as the basis for the experiments. Several chunks of the glass were placed in a platinum crucible and heated for about an hour at 950—1000°. The glass was cooled and broken out. It appeared very milky throughout. Another sample of the same glass was ground to pass 80 mesh, and heated for about two and a-half hours at 1400—1500°.

The glass when cooled quickly was perfectly clear. To determine whether milkiness could be developed, it was reheated for two and a-half hours at 900—1000°. It was then removed and cooled; a thin film of white, devitrified material formed on the surface, but the bulk of the glass was perfectly clear.

Another sample of the glass was ground to pass 80 mesh, mixed thoroughly with 2 per cent. of finely ground quartz, and heated for nearly two hours at 1400—1500°. After cooling, it was reheated at 1018—1042° for about three hours. The surface devitrification was a little greater than in the second experiment, but the material underneath was free from milkiness.

From the experiments, it is inferred that the original sample contained some ingredient which assisted the excess silica to crystallise out; when the glass was heated to 1500° approximately, this ingredient was volatilised. The result can scarcely be attributed to a change in alkali, for volatilisation would lead to a decrease rather than an increase.

The authors therefore agree that a final proof has not been obtained, but evidence points strongly to the fact that traces of SO_3 and Cl produce opalescence.

[The conclusions of Fenner and Ferguson in Abs. 24 and 26 agree closely with those previously obtained by J. D. Cauwood and W. E. S. Turner (this JOURNAL, 1917, **1**, 187), who studied the effect of small quantities of sulphate and chloride, the influence of temperature and of reheating.] A. M. J.

29. Optical Glass Melting. E. ZSCHIMMER (*Sprechsaal*, 1904, **37**, 1041, 1081).—One of the principal difficulties in the production of optical glass is the elimination of "cords." Cordy metal can arise in many ways. If the batch is not well mixed it will be produced; the solution of the pot walls in the metal is a very frequent cause; and the evaporation of the more volatile constituents, giving rise to a variation in constitution, also has this effect. Photographs of "cords" are given, one showing the cords proceeding from the pot walls.

Usually the glass is melted for about thirty hours and cooled down very slowly, this taking from four to five days. In this process the glass breaks into pieces, which are then put into shallow, rectangular moulds and heated to the softening point, when they sink and fill the moulds. The slabs thus obtained are cooled very slowly to prevent any strain arising.

It is pointed out that small bubbles in the glass do not affect its optical performance, but only its appearance. J. R. C.

30. Glass Making Processes. N. L. BOWEN (*Optician*, 1918, **56**, 193).—The article dealt generally with factors tending to produce non-homogeneity. According to the author, the more fusible portions of the batch liquefy and filter downward through the grains of the more refractory material. The sand was found usually to be the last material to dissolve, the grains tending to rise in the liquid, thus making the upper parts more siliceous and of lower density. Diffusion lessened this continuous density gradient in time, and appropriate stirring eliminated it. The action could be interrupted and observed at an intermediate stage; sand grains were then found suspended in the liquid, and, pointing down from each grain, a tail of glass of lower refractive index than the surrounding glass, thus affording a proof of the explanation. There were two other factors making for inhomogeneity—solution of the pot and the volatilisation of certain ingredients—but their effect was not regarded as so important as that of the sinking of the heavy liquid and the rising of the sand grains. J. R. C.

31. Scientific Glassware. Morris W. Travers (*J. Soc. Chem. Ind.*, 1918, **37**, 235).—The author explained how, persuaded by Mr. D. H. Baird, he decided to tackle the problem of manufacturing light hollow glassware which prior to the war was mostly obtained from enemy countries. Difficulties encountered throughout the manufacture are dealt with.

A large number of samples of glass were first analysed, noting the kind of article for which each sample was suitable, and testing the qualities and working properties of the glass.

A small oil-fired furnace, capable of founding about 1 cwt. of glass, was first erected, batches based on the analyses made were melted, and from these melts tube and hollow articles were made and their qualities tested.

From these experiments it was found that a soda–potash–lime–alumina glass equal to the best German lamp-working glass, and a resistance glass similar to the "Jena" resistance glass, but modified in a manner calculated to remove the objection that it gave up zinc to acids, could be manufactured.

Oil-firing, though applicable to tank furnaces, did not seem suitable for pot furnaces, so other furnaces heated by gas from coke in a producer were installed. Two Hermansen recuperative furnaces had also been installed in a new glass-house.

Experience in the matter of pot-setting had led the author to blame the glass manufacturer rather than the pot-maker for many of the mishaps to pots. He described the method of pre-heating pots now successfully followed in his own works.*

The author pointed out that investigations on the composition of glasses had so far only supplied us with the bare minimum of necessary information, and much correlated work by the chemist, glass manufacturer, and practical glass-blower was still necessary. There was scope also for a considerable amount of research on the mixing of batch and in connection with the mixing of batch and cullet. Observations had led to the conclusion that considerable advantage may be gained from the grinding of the cullet and mixing it with the batch.

In the author's view, the formation of "cords" in glass was well worth attention. Those which had their origin in ill-digested particles of clay, of scale from the pot, or from the material of the batch might be ruled out of investigation. The glass-maker would say that such cords were due to "lack of heat," which was true in the sense that if the pot were hot enough during the found even fairly large particles of clay will completely dissolve. Sometimes during the working of a pot of metal the glass "goes cordy" and remained cordy, but sometimes became clear again in a truly remarkable manner. This was possibly a surface phenomenon, and worthy of the attention of those who had made a study of colloids.

It would be of benefit to both consumer and manufacturer if it were possible to standardise chemical and bacteriological glass ware; at present, owing to the variety of goods to be manufactured and the comparatively small demand for them, the introduction of automatic and semi-automatic machinery was not practical politics. The author suggested that a 500 c.c. beaker should be about 0·8 mm. thick and a 1000 c.c. beaker 1·0 to 1·2 mm. thick. The articles must, of course, be evenly blown.

---

* See this Journal, T., 1918, **2**, 170 and 270.

Moulds used for the blowing of graduated flasks had often been noticed to shrink. Brass moulds are recommended.

Annealing presented many difficulties. In the case of scientific glassware, enormous bulk for small weight had to be dealt with, and as the goods must pass very slowly through the hot part of the lehr, unusually large lehr accommodation was required.

The lehrs used by the author were heated by means of producer-gas. The gas entered a space below the bed of the lehr, which was formed of a brick arch, and then passed up ports at the side. Secondary air entered through slides at the front and met the gas at the bottom of the ports, and the length of the flame issuing from the ports, and consequently the temperature of the lehr, could be increased or reduced by closing or opening the air slides. The temperature could be regulated to within 10°.

The fall of temperature along the lehr was regulated by taking away the hot gases into a flue through openings which were closed by dampers. Resistance glass could be removed from the lehr at 300°.

Beakers and similar pieces of apparatus had to be cracked off, flanged, and lipped. Badly annealed goods cracked off so as to to leave jagged edges, so that efficiency of production depended upon efficient annealing.

Problems of the graduating shop were touched upon, and the author, who pointed out that scientific literature included very few papers dealing with the accuracy of volumetric measurement, and that a great deal of work might well be done with a view to improve the ordinary dividing machine. A simple method was described for accurately determining volumes. A rod of pure nickel was bored and the hole rounded at the bottom. The end of the rod was then carefully ground until the capacity, determined by filling the vessel so formed with mercury and pressing a polished glass plate over the top, was exactly the volume required.

In calibrating an instrument like a burette, the glass tube was filled with water, allowed to drain to the zero level, and the height of the meniscus marked. The required volume of mercury was then poured into the burette from the nickel measure, and the sides of the tubes, being wet, the water meniscus rose by an amount equal to that which it would fall if the same quantity of water were allowed to flow from the apparatus.

Grinding, polishing, stoppering, and similar operations which in this country were usually performed by highly skilled workmen using very crude tools, demanded the attention of the engineer.

A. M. J.

32. Some Aspects of the Scientific Glassware Industry. F. W. BRANSON (*J. Soc. Chem. Ind.*, 1918, **37**, 337T).—In a previous communication (*J. Soc. Chem. Ind.*, 1915, **34**, 471; this JOURNAL, 1917, Abs., p. 15) the author gave analytical data on the composition of practically all the types of important chemical glassware imported prior to the declaration of war. His preference for chemical glassware was a zinc–alumina boro-silicate glass.

A Jena glass beaker obtained direct shortly before the declaration of war had the following composition:—SiO_2 64·66, Al_2O_3 6·74, ZnO 10·12, CaO 0·08, MgO 0·13, K_2O nil, Na_2O 7·21, B_2O_3 11·14, Fe_2O_3 0·10.

Numerous analyses and experimental meltings of the author indicated that with about 6·5 per cent. of Al_2O_3, 7·5—8·5 per cent. of ZnO, and about 7 per cent. of B_2O_3 a good glass was obtained which with perfect annealing was equal to all reasonable requirements for scientific work provided the silica and alkali were present in the best proportions. If the amount of ZnO were reduced, lime appeared to be the best substitute.

A proportion of about 6 per cent. of Al_2O_3 gave increased strength to the glass and diminished the action of the melted glass on the pots.

A zinc–aluminium boro-silicate obtained by the use of a good formula was not expensive to make, and did not devitrify. It had good working properties, and was therefore a favourite with workmen owing to its good plasticity over a wide range of temperature. It made excellent glass tubing for the manufacture of glass apparatus and ampoules.

In addition to the above, a considerable quantity of aluminium boro-silicate and other types of scientific glassware of excellent quality were being made by other firms. (For analyses of British glasses, see *J. Soc. Glass Tech.*, 1917, **1**, 196).

A great aid to the industry would, in the author's view, be the standardisation of hollow scientific glassware, such as beakers and flasks, as to shape, contents, and weight.

The author strongly emphasised the importance of good annealing. A careful determination of the exact temperature for annealing, without deformation, a glass which approximated in composition to the general formula given above was 580°. The articles were tested by means of a Hilger's strain-viewer.

Reference was made to the work of Twyman (*J. Soc. Glass Tech.*, 1917, **1**, 61), and of English and Turner (*J. Soc. Glass Tech.*, 1918, **2**, 90), on annealing.

The question of increasing the resistance of glass by re-annealing was raised. Dr. W. E. S. Turner stated that experiments carried out in his laboratory did not reveal any difference in resistant power due to re-annealing, whilst he further pointed out that experiments carried out at the National Physical Laboratory failed to bring to light any difference between the ordinary annealed and the re-annealed (with flue gases containing sulphur dioxide) Jena ware. A. M. J.

33. Chemical Glassware. P. H. WALKER (*J. Amer. Chem. Soc.*, 1905, **27**, 865).—An abstract of this paper has already appeared under Transactions, 1917, **1**, 165. V. D.

34. The Use of Quartz Glass in Chemistry. M. BERTHELOT (*Compt. rend.*, 1905, **140**, 817).—The author found quartz glass very useful in the study of reactions at very high temperatures. It is easily worked in the oxy-hydrogen, or, better still, in the oxy-acetylene, flame, and uniform tubes can be obtained which will resist a pressure of three atmospheres up to the softening point, 1400°.

Acids do not attack these tubes, and they can be cooled by plunging them into cold water whilst at a red heat. V. D.

35. The Permeability of Quartz Glass. M. BERTHELOT (*Compt. rend.*, 1905, **140**, 821).—Quartz glass vessels had previously been shown to be permeable by hydrogen and helium (Villard, *Compt. rend.*, 1904, **138**, 1033, and Jacquerod and Perrot, *ibid.*, 1904, **139**, 789), but the author has carried the investigation still further, observing the exchange which takes place between the gases enclosed in the vessels and the atmosphere.

On heating carbon in a quartz glass tube maintained at a temperature of 1300—1325° for half an hour, it was found that the tube contained nitrogen and carbon monoxide, showing that the elements of the atmosphere had entered the tube by endosmose. Similarly, when 4 c.c. of oxygen were enclosed in a tube and heated at 1300° for one hour, 3 c.c. of nitrogen were found in the tube on cooling.

The hydrocarbons naphthalene and methane were heated in a similar way, and at the end of an hour nitrogen was found to have entered the tube, which also contained some carbon and a little hydrogen. Thus, at the high temperature of the experiment these compounds were split up into their elements, the hydrogen escaping into the air through the walls of the vessel, and the elements of the atmosphere entering, showing that quartz glass behaves like animal membranes, allowing gases to pass through it by a process of osmosis. V. D.

36. The Permeability of Quartz Glass Tubes. M. BERTHELOT (*Compt. rend.*, 1905, **140**, 1159).—Tubes of quartz glass were found permeable by hydrogen at high temperatures, the transpiration being very rapid at a temperature of 1300°. At the ordinary temperature, such transpiration was not evident even after many days' exposure, and not appreciable, if it existed at all, at 600—800°.

The passage of hydrochloric acid gas through the walls of a quartz glass tube was not noticeable below a temperature of 1400°, while that of carbon dioxide was only slight at 1300°.

The transpiration of nitrogen was not sensible at 800°, was slight at 1000°, but was appreciable at 1300—1400°, though even at this temperature it was much less rapid than that of hydrogen at the same temperature.

Oxygen permeated the tubes much more rapidly than nitrogen, but not so rapidly as hydrogen. Using air as the enclosed gas, and introducing a quantity of known volume under normal temperature and pressure, the tube was sealed and heated at a temperature of 1400° for an hour. The pressure of the hot gas caused the softened quartz to swell, but when the contained gas was reduced to normal conditions its volume was less than the original volume, and the percentage of oxygen was 17·7, whereas the air originally contained 20·8 per cent. of oxygen.

Under these conditions, then, approximately one-sixth of the initial volume of nitrogen and one-third of the initial volume of oxygen had passed from the tube, this ratio being very similar to that in which the gases of the atmosphere dissolve in water.

V. D.

37. The Permeability of Glass Vessels. M. Berthelot (*Compt. rend.*, 1905, **140**, 1286).—A vessel of glass or silica softens at a high temperature, and the walls acquire properties resembling those of a colloidal solid, such as caoutchouc. Gases enclosed in the vessel diffuse through its walls, and the gases of the surrounding atmosphere pass inwards.

When the glass or silica is heated to its softening point, the walls of the vessel are thinned by internal pressure, and this permeability is then most evident. As soon as the temperature is lowered below the softening point, the transition ceases.

The author has carried out his investigations using tubes of different kinds of glass, viz.: (1) ordinary white glass, softening at 550° and becoming plastic at 650°, and (2) Jena glass, softening at 750°. The tubes contained hydrogen, oxygen, and carbon monoxide, and in all cases the experiments proved that in the neighbourhood of the softening temperature the transition of the gases took place according to the laws of diffusion through permeable membranes, the gas diffusing out and air diffusing in. V. D.

38. The Filming of Glass. (*Trans. Optical Soc.*, 1918, **19**, 184).—An abstract of a discussion held by the British Optical Instruments Manufacturers' Association. Generally speaking, glasses showing the greatest affinity for water gave the most trouble. The chemical constitution of the lubricants used in optical instruments appeared to have an important bearing on the subject. A high degree of potash was requisite, as small pits, scratches, etc., on the surface tend to act in the same way as dust particles, namely, as nuclei around which film was deposited. It was suggested that investigations should be carried out in order to find a more suitable lubricant, one that was free from unsaturated compounds, for use in optical instruments. It was also suggested that better ventilation should be provided between the different chambers of an instrument, and that such instruments should be so designed as to permit of easy access to the glass surfaces for the purpose of cleaning.

The results of tests on seventeen samples of glass were presented. The tests were: (1) The alkalinity of a freshly-broken surface which has been weathered for seven days in an atmosphere at 180°, saturated with water vapour, the number of mg. of iodeosin precipitated on 1 sq. m. of surface being taken as a measure of the weathered alkalinity. (2) The glass was subjected for thirty hours to the action of clean air at 80°, saturated with water vapour, and the deposit on, or corrosion of, the surface was examined microscopically. The glasses were classed as: (i) unaffected or only slightly affected; (ii) decidedly affected; (iii) very seriously affected. In the following table + indicates that the glass was rather more, and − that it was rather less, affected than the standard for the class:—

						Results of test.	
Sample.	Maker.	Type.	Melting.	N_D.	ν.	1	2
0	Schott & Gen	H.F.	O5916	1·6241	35·7	37	2
1	Chance	B.S.C.	3401	1·5078	64·0	24	2−
2	Schott & Gen	B.S.C.	—	1·5188	60·4	36	2+
3	—	Spectacle Crown	—	—	—	43	2+
4	Schott & Gen	B.L.F.	—	1·555	48·2	60	2+
5	Graillot	B.L.F.	1056	1·559	50·6	12	1+
6	Chance	B.L.F.	3684	1·5503	51·8	28	2
7	Chance	H.C.	3504	1·5163	60·5	26	2
8	Chance	M.B.C.	3359	1·574	57·7	6	1+
9	Schott & Gen	B.S.C.	O7302	1·5765	64·0	6	2
10	—	Plate	—	—	—	28	3
11	Chance	L.F.	1044	1·5791	40·5	17	1
12	Mantois	L.F.	9040	1·574	42·7	13	2
13	Chance	H.F.	3867	1·6211	36·2	12	1
14	Chance	H.F.	3621	1·6223	36·1	11	2
15	Chance	Soft C.	3532	1·5138	56·9	52	3
16	Graillot	E.D.F.	1126	1·652	33·6	11	1+

J. R. C.

39. On the Compressibility of Solids. J. Y. Buchanan (*Proc. Roy. Soc.*, 1904, **73**, 296).—The method used to determine the compressibility of several metals was that used in 1880 for investigations on glass. The method was briefly described. The linear compressibility was measured, and the cubic compressibility obtained from this. In addition to the evaluation of the desired quantity for five metals, determinations were also made with English flint glass, density 2·968, and German tubing glass, density 2·494. The linear compressibility, that is, the decrease in unit length, per atmosphere pressure, multiplied by 10^6, was, for the former, 1·02, and for the latter 0·846. The compositions of the glasses were not given. J. R. C.

40. Resistance to Compression of Glass and Quartz. G. Berndt (*Verh. d. D. Phys. Gesell.*, 1917, **19**, 314; abs. from *Deutsch. Mech. Zeit.*, 1918, 114).—The machine referred to in

Abs. 84 was used for the purpose of ascertaining the resistance to compression of mirror glass and quartz. The test-pieces, which were cubes of 5, 8, 10, and 15 mm. edge, were compressed between plane, hard, polished steel plates. A new plate was used for every test, so that the surface was always accurately plane and there was no tangential strain. The following results were obtained, the pressures being expressed in kg./cm.^{2}:—

Length of cube edge.	Mean value of pressure for several tests.	Highest value.
5 mm.	12,000	13,000
8 ,,	10,300	10,400
10 ,,	9,000	10,000
15 ,,	8,700	8,800

The surfaces in contact with the steel were polished; the other faces sometimes polished, sometimes finely ground. Experiment showed that the condition of these surfaces was immaterial; nevertheless, in the later tests all were polished. The pressure was gradually applied until the cube burst. Slight inequalities of the compressed surfaces caused the cube to split prematurely. The values obtained in these cases were disregarded. The pressure producing fracture was found to be independent of the time when this was varied from a few seconds to five minutes. Periods of from one-half to one minute were usually employed.

One cube with a 5 mm. edge exhibited an interesting behaviour when compressed. It was subjected to a pressure of 3,000 kg. without breaking, and when the pressure was released it was seen that a cylinder had been cut out of the cube. It appears that the effective area of pressure is a circle, and it was found that cylinders 5 mm. high and 5 mm. in diameter withstood the same pressures as the cubes of 5 mm. edge.

Glasses for these tests must be homogeneous and perfectly annealed. To illustrate the effect of imperfect annealing, the borosilicate crown 516/640 of the Sendliger Optical Works was used. Two specimens were employed, one very notably strained and the other very well annealed. The test-pieces were cylinders of 5 mm. diameter, and the following results were obtained:—

	Load.	Mean value.	Max. value.
Strongly strained.	Continually increasing	15,000	18,400
	Increasing by steps	15,200	17,500
Annealed.	Continually increasing	14,200	16,900
	Increasing by steps	12,500	15,100

When quartz was tested, the steel plates were compressed, on account of its hardness. The cylinders split very often, but the values of the crushing strength arrived at were:—

	Parallel to the optical axis.	Perpendicular thereto.
Mean	25,000	22,800
Maximum	28,000	27,400

J. R. C.

41. The Annealing of Glass. (*Proc. Tokyo Phys. Soc.*,' 1918; *J. Ind. Eng. Chem.*, 1919, **11**, 244).—If a newly drawn glass fibre is heated slowly in an electric furnace and its length observed, it is found first to increase as the temperature rises, and then at a temperature about 400° it begins to contract, whilst at 500° it becomes elastic; also, if a short cylinder of glass between crossed Nicols is heated, the interference rings show little change until 400° is reached. Then they widen and disappear at about 500°. (See also this JOURNAL, 1918, **2**, 90.)

When glass is slowly heated or cooled, the temperature curve shows that over the plastic range there is absorption or liberation of heat, proving that some change of state of a constituent of the glass takes place at that temperature. The first two effects vary with the nature of the glass, and are not exhibited by annealed specimens, but the third effect is found in both annealed and unannealed glass. S. E.

42. Antimony Oxide as an Opacifier in Cast Iron Enamels. J. B. SHAW (*J. Amer. Cer. Soc.*, 1918, **1**, 502).—According to the author, antimony oxide is equivalent to tin oxide, pound for pound, as an opacifying agent, and whilst tin oxide is dear, antimony compounds are fairly cheap; hence, the use of the latter in enamels for ironware is worth considering as a commercial proposition.

To obtain some idea of the value of antimony oxide in the above connection, experimental melts were made, the work being carried out in three stages:—(1) 500 gram batches, in a laboratory furnace; (2) 75 lb. batches, which were melted and applied to commercial wares; (3) 2000 lb. batches, melted and applied to commercial wares on a works scale.

Knowing the efficiency of cryolite as a flux and opacifier in enamels, trials were made with a view to determine the possibility of using it in conjunction with antimony oxide.

Forty-four batch compositions of melts are given in the paper. From the experiments, it was concluded that whilst good colours were easily obtained, it would not be possible to utilise the fluxing power of cryolite to advantage, as the range of composition of enamels suitable for the iron was so small. Another series of enamels was tried, using felspar, borax, soda-ash, nitre, barium carbonate, zinc oxide, and antimony oxide, but no lime or cryolite. Such enamels all failed, retaining the consistency of soap-suds even after intense heating.

A third series, containing fluorspar in addition to the materials mentioned above, was found to give the best results.

The control of crazing and shivering is stated to be best accomplished by varying the silica content. The fusibility was similar to that of ordinary tin enamels, and the opacity quite as good.

It was found that the following conditions require emphasis:—

(1) Only the purest white antimony oxide must be used, other-

wise the colour of the enamel is liable to be similar to that of the oxide itself.

(2) Excessive smelting will produce a bluish-green colour in any antimony enamel containing fluorspar and a low percentage of lead. The fluorspar should therefore not exceed more than 5 per cent. of the raw batch.

(3) Thoroughly oxidising conditions (plenty of nitre) must be maintained at all times during the melting of antimony enamels. Reduction causes the development of a green colour.

(4) Manganese dioxide (up to 0·4 per cent.) may be used to mask the bluish-green colour of the fluorspar–antimony compound. An ivory-green colour results from the use of low fluorspar or insufficient smelting, or both. The addition of 1 per cent. of lead oxide will sometimes convert a useless, leadless antimony enamel into one having a pleasing cream colour. A high lead content is not, however, permissible with antimony, because the combination produces a yellow colour.

(5) Cryolite is unsatisfactory as a flux or opacifier in antimony enamels, but small quantities (up to 3 per cent.) will aid in producing a good colour, and that without introducing any troublesome element.

(6) Extreme care in proportioning the raw materials, very careful and thorough mixing, and proper melting will insure the successful use of antimony oxide. A. M. J.

43. A Glass of Low Resistivity. C. E. S. Phillips (*Brit. Assoc. Reports*, 1906, Sect. A).—When sodium silicate and borax were fused together in the following proportions, a glass was obtained which conducted electricity fairly well: sodium silicate, 32 parts; calcined borax, 8 parts.

By the addition of 1·25 parts of Powell's flint glass, the stability was increased, and the surface improved without decreasing the conductivity. This glass was found suitable for use in cases of electrostatic instruments. It could be cast into plates, but was not otherwise very workable, due to its low fusion point. It took a fine polish, had a density of 2·490, and was somewhat harder than the ordinary soda glass of commerce.

No fluorescence was shown by this glass under cathode radiation, and while it was transparent to *X*-rays, it was opaque to ultra-violet light. Its specific resistance was of the order of 10^9 ohms at 20°, and its electrical conductivity about 500 times that of any glass made previously. In the form of a powder it could be fused on to copper, adhering without cracking. V. D.

44. Phosphorescence caused by the β- and γ-Rays of Radium. G. T. Beilby (*Proc. Roy. Soc.*, 1904, **74**, 511).—The author noted that a piece of potash glass exposed to the rays showed a feeble fluorescence. After it was removed from the radiation, the place where the rays had entered the surface was found to be coloured brown. The patch phosphoresced feebly. Six weeks afterwards there was no phosphorescence until the glass was heated to 100°, when it gave a faint, green glow. On heating to 200°, the brown patch disappeared.

A lens of colourless flint glass phosphoresced feebly while under the influence of the radium, but not when removed therefrom, and exhibited no revived phosphorescence when heated to 200°. This heating caused a brown coloration, which had resulted from the action of the rays, to disappear. J. R. C.

45. On the Coloration of Glass by Natural Solar and other Radiations. W. Crookes (*Proc. Roy. Soc.*, 1904, **74**, 524).—The paper described the coloration of two pieces of transparent glass sent to the author from South America. They were taken from rubbish heaps, where they had been exposed to the action of the sun for a long time at a high altitude. The specimens were coloured an intense purple. It appears probable that the coloration was due to the presence of manganese in the glass, this being affected by the solar rays of short wave-length which would be present at an altitude of 4,000 metres, but not at sea-level, owing to atmospheric absorption. The colour disappeared when the glass was re-heated to the softening point, but could be reproduced, in a short time, by exposure to the β- and γ-rays of radium. Examination showed that the coloration was not superficial, but had penetrated throughout the mass. J. R. C.

46. The Action of Ultra-violet Light on Glass. F. Fischer (*Physikal Zeitsch.*, 1905, **6**, 216).—Eight specimens of glass were exposed to the action of light of short wave-length, and it was found that four of them were coloured, namely, ordinary Thuringian glass, two kinds of Thuringian "apparatus" glass, and Jena normal thermometer glass. The following remained uncoloured: Jena "telescope" glass, Jena Durax glass, German lead glass, and English lead glass. Analysis showed that the first four contained manganese and the others did not. The colours disappeared when the glasses were heated to the softening point and cooled. The explanations given by Crookes (this vol., Abstract No. 45) apply equally to these observations. J. R. C.

47. The Fluorescence produced by Radio-tellurium in Glass, Mica, and Quartz. H. Greinacher (*Physikal Zeitsch.*, 1906, **7**, 225).—The glass walls of a vacuum tube, in which was a copper plate covered with radio-tellurium, were observed to fluoresce most in the neighbourhood of the plate. Investigation of the fluorescence produced in plates of glass and mica and in a quartz lens by this substance showed that the effect is greatest at the surface, and is probably due to the easily absorbed α-rays. J. R. C.

48. The Observation and the Determination of the Magnitude of Ultra-microscopic Particles, with particular application to Gold Ruby Glass. H. Siedentopf and R. Zsigmondy (*Ann. Physik*, 1903, **10**, 1).—All ruby glass, no matter what the colouring agent, is at first optically clear. The colour appears when the glass is re-heated, or when it is very slowly cooled in the pot, and is caused by the separation of finely divided metal particles. Hitherto, there had been no determinations of the size or other properties of these particles. It had only been assumed that, as they were not microscopically visible, their magnitude must be less than half a wave-length of light. The authors described a method whereby the particles may be observed, the method being applied to gold ruby glass.

The paper is divided into three sections. In the first, the apparatus was described. A small volume of the glass was laterally illuminated by concentrated sunlight, and the diffraction discs caused by the ultra-microscopic particles examined in a direction perpendicular to the illuminating beam. The description is very complete, and details are given of the order in which the various adjustments should be made to obtain the best results. The condition of polarisation of the diffracted light was discussed. The limit to the size of the particles which can be observed by this method is theoretically considered, and a limiting value of 6×10^{-6} cm. is derived.

In the second section, the determination of the size of the particles is described. The particles in a definite volume were counted, and their size calculated from the specific weight of the gold and the total mass of the metal found by analysis. It was assumed that the particles were cubical in shape.

The sources of error of the method, which are numerous, were exhaustively discussed, and their influence on the final result considered. A method, which can be accomplished quickly, for the approximate determination of the size from the distance between the particles was briefly described. It was shown that a conclusion as to the size could be drawn also from the brightness of the diffraction discs formed by the particles.

In section three, the relation between the colour and the particle size was considered. It was pointed out that the treatment of the glass affected the colour and the size of the particles. It was noticed that streaks were of a slightly different composition from the rest of the glass, and so the condition of the gold particles was different; there was also a difference in colour. The colour of the glasses examined, their appearance in polarised and unpolarised light, the gold content, and the probable size of the particles were summarised in two tables. The colour could not be connected with the particle size. It was shown that gold particles must exist which have some colouring action, but are smaller than can be observed by the method described. J. R. C.

49. Colours in Metal Glasses and in Metallic Films. J. C. M. Garnett (*Phil. Trans.*, 1904, *A*, **203**, 385; 1906, *A*, **205**, 237).—The phenomena which these papers seek to explain were observed by Siedentopf and Zsigmondy (Abstract, No. 48). The author showed that the particles observed by Siedentopf and

Zsigmondy in gold ruby glass are spherical in shape when the diameters are less than 10^{-5} cm. An investigation into the optical properties of a medium containing such metal spherules shows that every such medium has a definite colour by transmitted light, depending on the optical constants of the metal, the quantity of it in unit volume, and the refractive index of the medium, but not on the size or distance apart of the spherules. Their presence accounted for the optical properties of gold ruby glass, and it was proved that the irregularities in the effects of colour and polarisation sometimes exhibited by gold glasses were due either to the excessive distance apart of the particles or their excessive size (greater than 10^{-5} cm.). The method of inquiry adopted enabled one to predict, from a knowledge of the metal present in metallic form in a glass, what colour that glass would be. For example, if the metal were gold, a glass the refractive index of which for the D-line is 1·56 will transmit more red than yellow, a silver glass will transmit more yellow than red, and a "potassium–sodium" glass more blue than yellow. A very slight separation of sodium or potassium would give a very strong blue or violet coloration. It seemed to the author probable that the violet coloration of X-ray soda-glass bulbs was due to this separation,* as it was found that the red colour could be produced in colourless gold glass by exposure to β-rays. A piece of this glass placed in a tube containing radium emanation exhibited an unmistakable ruby tint within two days.

In the second part of this paper the colours of metallic films were discussed. It was mentioned in an appendix that large particles of gold (diameter greater than $0{\cdot}1\,\mu$) in a glass would, by removing the red and yellow light by reflection, give the glass a blue colour by transmitted light and a brown turbidity by reflected light.

In the second paper, the consideration of the structure of metal glasses was resumed. Curves were given representing the absorption by specimens of gold ruby glass, silver stained glass, and copper ruby glass. A comparison of these curves with the graphs for gold spheres and molecules in glass led the author to the conclusion that the colour of gold ruby glass was primarily due to the presence of the small spheres. The irregular blue and purple colours sometimes exhibited were explained by the presence of coagulations of the spheres. The close similarity between the observed absorptions of yellow glass produced by staining with silver and the calculated absorptions by a diffusion of silver spheres in glass indicated that the stained region must contain such spheres. Their presence also accounted for the blue reflection from the internal face of the stained layer. A comparison of the observed and calculated absorptions of copper ruby glass showed that, in this case also, the colour was due to small metallic spheres. On the other hand, the metals which coloured some other glasses cannot be present in metallic form; for example, cobalt in this condition would give a reddish-brown colour by transmitted light, not the deep blue of cobalt glass.

---

* Colour possibly due to manganese in the glass. See Abs. 45.—Ed.

The colours in metallic films and in metallic solutions were further discussed in this paper. J. R. C.

50. The Physical Basis of Colour-Technology. M. Luckiesh (*J. Franklin Inst.*, 1917, July, 1).—The chief methods of analysing colour are by means of the spectrophotometer, the monochromatic colorimeter, and the trichromatic colorimeter. The first of these provides data of greater physical usefulness than the others, and the paper dealt with results chiefly obtained in this manner. Three classes of coloured media were discussed, namely, pigments, dyes, and coloured glasses. Coloured glasses were more nearly related to dyes than to pigments. A given concentration of colouring material in a glass apparently obeyed the same law relating to thickness and transmission factor for a given wavelength as a dye solution. It was not established, however, that the introduction of various amounts of the colouring material resulted in corresponding concentration; the uncertain conditions of melting made this point difficult to decide. The physics of the process by which glasses are coloured by means of metallic compounds was not wholly clear. It was considered that metals colour glass in two ways, one by being in a state of true solution in the glass, and in the other by being in a colloidal state. In this connection, reference was made to the work of Garnett and of Siedentopf and Zsigmondy (this vol., Abstrs. No. 49 and 48).

Spectral analyses of a number of pigments and dyes were tabulated, reflection factors being given in the former case and transmission factors in the latter. To simplify the study of coloured media, especially dyes and coloured glasses, laws have been formulated by theory and confirmed by experiment. Lambert's law, that all layers of equal thickness of a medium absorb equal fractions of the incident radiant energy, was well established, but there appeared to be some doubt as to the validity, especially in the case of "colloidal" glasses, of Beer's law, that the absorption is the same function of the concentration of a dispersing absorbing substance as of the thickness of a single substance. Assuming the truth of these laws, the spectral analyses of coloured solutions and glasses, of any thickness and concentration, could be obtained from two determinations of spectral character. This method had been found practicable in the development of coloured glass and in the study of many problems arising in colour technology. It was usually applied graphically, and examples were given illustrating the uses of the scheme in practice. In the development of coloured glasses there were sometimes chemical considerations which alter the predictions based on computation, but the procedure formed a working basis.

The spectral analyses of some fundamental coloured glasses were presented, and also the results of some simple combinations. Selenium, copper, and gold were the colouring agents for red glasses. No single element isolated spectral yellow, but carbon, sulphur, uranium, and silver produced yellow glasses of varying colour. Iron, chromium, and copper imparted green and bluish-green colours to glass when introduced under proper chemical conditions. Cobalt, which was most commonly used for blue glass, transmitted also a deep red band. If a cobalt-blue were combined with a copper bluish-green, the latter absorbed the red, and an excellent blue glass was obtained. Nickel and manganese produced a purple colour, but the latter was not an efficient purple, as its absorption band was not sharp. The author considered that, in such cases as street-lighting glassware, it would be better to eliminate the manganese and to endure the unneutralised green hue of the iron, on account of the reduction of the transmission factor consequent on the introduction of the manganese. This reduction was accentuated after the glass had been exposed for some time to intense sunlight or arc radiation, when the originally clear glass might be coloured to a deep purple.

In developing a coloured glass for a specific purpose, various factors were to be considered, such as the illuminant to be used and the result to be obtained. From these, an ideal spectral transmission curve was determined, and by means of the spectral analyses of different coloured glasses, bearing in mind the chemical considerations if a mixture were finally necessary, various combinations could be made with the aid of the graphical method.

J. R. C.

51. The Influence of Temperature on the Absorption of Light in Isotropic Bodies. R. A. Houston (*Ann. Physik*, 1906, **21**, 535).—The effect of temperature on the absorption bands of seven glasses and seven dye solutions was investigated with a spectroscope and a spectrophotometer. The glasses were coloured by didymium, uranium, gold, copper, and cobalt, and there was a "potash manganese" glass. If d is the ratio of the intensity of the light after transmission to the original intensity and l is the thickness of the glass, then the quantity $nk = -\lambda \log d/4\pi l \log e$ is called the "absorption index" of the medium for light of wave-length λ. This quantity was tabulated for various wave-lengths for all the glasses, both at the ordinary temperature and at a temperature in the neighbourhood of 300°, and curves were given which represent the variation graphically.

Didymium glass exhibited ten narrow absorption bands in the visible spectrum. On heating, some of these bands coalesced, and this was believed to be due to one set being produced by praseodymium and the other by neodymium, the one group increasing in intensity and the other decreasing until the border line is indistinguishable. Uranium glass was found to have two absorption bands, both of which were noticeably weakened when the temperature was raised. The effect of heating was most pronounced in these two cases, but there was some change in all. The author held that there was no displacement of absorption bands with rise in temperature, only an alteration in the distribution and magnitude of the absorption.

The theory of absorption was discussed along the lines originated by Drude. The results obtained with two gold ruby glasses were the only ones which agreed at all well with the theoretical formula, and the theory was extended by the introduction of the idea of the reciprocal action of the electrons in an attempt to reconcile it with the other results.

The effect of pressure on the absorption was experimentally investigated, but the apparatus was not sufficiently sensitive to indicate the effect. J. R. C.

52. The Measurement of Absorption in Tinted Glasses. L. W. Phillips (*Trans. Optical Soc.*, 1904—5, 43).—Observations were made on a number of blue and green glasses, using the Simmance-Abady flicker photometer. The composition of the glasses was not recorded. J. R. C.

53. Silicate Specific Heats. W. P. White (*Amer. J. Sci.*, 1919, **47**, 1).—This paper extends in scope and accuracy some work previously published. The charges of silica or silicate tested were heated in electric or steam heaters, with particular care to secure both constant and uniform temperatures, and were dropped into the calorimeters by an automatic arrangement, which secured uniformity and quickness. A large number of precautions against error were employed, and these were described in detail. The mean specific heats for eight intervals, ranging from the interval 0° to 100° to that of 0° to 1400°, were determined for nine substances, namely, cristobalite, anorthite, andesine, albite, microline, wollastonite, diopside, magnesium silicate amphibole, and magnesium silicate pyroxene.

For quartz and silica glass, the values of the interval specific heats to 100°, 300°, and 500° satisfy the expressions:

Quartz	$0{\cdot}1685+0{\cdot}000194\theta-0{\cdot}00000011\theta^2$
Silica glass	$0{\cdot}1670+0{\cdot}000189\theta-0{\cdot}000000125\theta^2$

The mean atomic heats at different temperatures were calculated by a method which was explained, and the results tabulated, for fourteen temperatures from 0° to 1300°. A useful comparison of these results with previous work was given.

In a lengthy section, devoted to the conclusions to be drawn from the experiments, attention was directed to the variations of the atomic heat, which should be a universal constant according to the kinetic theory. A comparison was also made between the specific heats of the substances as glasses and in the crystalline form. Every crystalline substance was also examined in the form of glass. The specific heat of the glass was usually little, if any, greater than that of the crystal. The exceptions to this rule occurred in the glasses containing sodium or potassium, and might be connected with the fact that these substances tend to impart

Interval Specific Heats.

	0—100°	0—300°	0—500°	0—700°	0—900°	0—1100°	0—1300°	0—1400°
Quartz	0·1869	0·2169	0·2380	0·2543	0·2596	0·2641	—	—
Pseudo-wollastonite	0·1844	0·2045	0·2170	0·2258	0·2324	0·2379	0·2426	0·2449
Cristobalite	0·1883	0·2333	0·2426	0·2508	0·2569	0·2625	0·2662	0·2680
Anorthite	0·1902	0·2143	0·2297	0·2399	0·2481	0·2551	0·2629	0·2674
Andesine	0·1925	—	0·2330	0·2441	0·2524	—	—	—
Albite	0·1948	0·2203	0·2363	0·2474	0·2561	0·2630	—	—
Microline	0·1870	0·2108	0·2262	0·2371	0·2450	0·2511	(0—1160°)	(0—1250°)
Wollastonite	—	—	—	0·2274	0·2344	0·2401	0·2416	—
Diopside	0·1924	0·2163	0·2314	0·2421	0·2500	0·2563	—	0·2603
Magnesium silicate amphibole	0·2033	0·2298	0·2461	0·2576	0·2661	0·2730	—	—
Magnesium silicate pyroxene	0·2039	0·2309	0·2484	—	—	—	—	—

Glasses.

	0—100°	0—300°	0—500°	0—700°	0—900°	0—1100°
Silica	0·1845	0·2124	0·2302	0·2423	0·2512	—
Anorthite	0·1885	0·2152	0·2305	0·2405	—	—
Andesine	0·1934	0·2211	—	0·2484	0·2615	—
Albite	0·1977	0·2238	0·2410	—	0·2640	—
Microline	0·1919	0·2163	0·2321	0·2431	0·2515	0·2598
Wollastonite	0·1852	0·2078	0·2203	0·2355	—	—
Diopside	0·1938	0·2189	0·2333	0·2439	—	—
Magnesium silicate	0·2040	0·2302	0·2474	0·2598	—	—

exceptionally high expansion coefficients to glasses in which they occur. Several of the glasses showed a decided increase in specific heat at some fairly elevated temperature, and it seemed probable that this increase would have appeared in other glasses if they had been tested at higher temperatures.

In quartz, below the α-β-inversion at 575°, the heat absorption was much less than corresponds with the abnormal expansion, and the author considered that quartz, and probably other forms of silica, exhibit what appear to be two kinds of inversion, due to different mechanisms. This question was exhaustively discussed by him. J. R. C.

54. Temperature–Viscosity Relations in the Ternary System Lime–Alumina–Silica. A. L. Feild and P. H. Royster (*U.S. Bureau of Mines*, Tech. Paper, 189, 1918).—The authors confined themselves to that range of composition encountered in iron blast-furnace slags. Synthetic melts were made and their viscosities measured at temperatures ranging from the melting point to an upper limit of 1600°, an electric furnace being used and the temperatures measured by a Holborn-Kurlbaum optical pyrometer. The viscosity was estimated by rotating the graphite crucible containing the melt and determining the torque on a steel ribbon used to suspend a graphite rod in the axis of the crucible. In the binary system calcium metasilicate–*gehlenite* ($Ca_2Al_2SiO_7$), a maximum viscosity at temperatures between 1350° and 1600° was shown by a mixture of about 30 per cent. of *gehlenite* and 70 per cent. of calcium metasilicate, and a minimum viscosity by the eutectic mixture. At the saturation temperature and at 50° and 100° superheat, respectively, the binary eutectic exhibited maximum viscosity when compared with contiguous mixtures. Viscosity–temperature measurements were made of mixtures representing seven quintuple points of the ternary system. Two of these mixtures (CaO 47·2, Al_2O_3 11·8, SiO_2 41, and CaO 49·5, Al_2O_3 43·7, SiO_2 6·8) did not obey the usual rule of possessing a viscosity–temperature curve continuous at the melting point, so that crystallisation of these mixtures should proceed without difficulty. Viscosity measurements were made of compositions lying on the boundary curves between the fields of calcium metasilicate and *anorthite*, calcium metasilicate and *gehlenite*, *gehlenite* and *anorthite*, and calcium orthosilicate and *gehlenite* at temperatures of 1400°, 1500°, and 1600°. Each of the viscosity–composition curves terminated at a quintuple point representing a eutectic, and included between these two ternary eutectics the binary eutectic between those two compounds the stability of which yielded its limits. In the boundary curve between calcium orthosilicate and *gehlenite* there were also two quintuple points where *gehlenite* α- and β-calcium orthosilicate are in equilibrium with their melt. The viscosities of the mixtures corresponding with these two points were much higher than for any composition lying in this part of the system; this appears to be due to the existence of the molecular aggregate identified with β-calcium orthosilicate. In each of these boundary curves the viscosity increased from a minimum at a binary eutectic to a maximum at a quintuple point. It was found that the viscosity surfaces were not of a simple nature at any given temperature, and their form depended greatly on the temperature. The investigation of what occurred in manufacturing processes involving molten silicates was still further complicated by the fact that even an approach to equilibrium is seldom obtained.

C. M. M.

55. Slag Control in the Iron Blast Furnace by means of Slag Viscosity Tables. A. L. Feild (*Chem. and Met. Eng.*, 1918, **19**, 294).—The author showed in the form of a curve the diminution of slag viscosity with increase of temperature, by means of which curve it could be demonstrated that a minor change in percentage of one of the principal constituents—lime, alumina, and silica—might cause a great change in the temperature–viscosity relations. A gradual increase in the amount of lime, instead of producing a gradual change in viscosity, produced maxima and minima. Changes in percentages of minor constituents of a slag, such as oxides of magnesium, manganese, iron, etc., did not appreciably affect temperature–viscosity relations if the percentage of magnesia, the most important minor constituent, did not exceed 8 per cent. The temperature relations of a slag were said to be most suitable with a viscosity ranging from 10 in the furnace to a viscosity of 4 where the slag leaves the furnace. In controlling the slag between these limits, it was shown that the calculations of slag analyses must be made on a basis of 100 per cent. of lime, alumina, and silica. Lime must be accurately determined by analysis, and not by difference, as slag properties were particularly susceptible to slight differences in the lime content. C. M. M.

56. Some Mixed Crystals of Calcium Ferrite and Aluminate. Edward D. Campbell (*J. Ind. Eng. Chem.*, 1919, **11**, 116).—In this investigation the author hoped to redetermine the existence or non-existence of a calcium ferrite of the empirical formula $5CaO,3Fe_2O_3$, and to obtain some experimental evidence as to what is formed when a mixture of calcium oxide, ferric oxide, and alumina was melted and then cooled at a rate slow enough to permit the material to be nearly in equilibrium during the entire cooling period.

The investigation led to the following conclusions:—

(1) That dicalcic ferrite and monocalcic ferrite are the only definite compounds of CaO and Fe_2O_3.

(2) That pure tricalcic aluminate may be recovered by crystallisation from a solution of CaO in $5CaO,3Al_2O_3$ as a solvent, provided the concentration of CaO at the beginning of the crystallisation is less than that which would be required to form tricalcic aluminate with all the Al_2O_3 present.

(3) That if a solution with the empirical formula $8CaO,3R_2O_3$,

containing both Fe_2O_3 and Al_2O_3 in the molecular proportion of 2 to 6, be slowly cooled, mixed crystals with Fe_2O_3 and Al_2O_3 in the ratio 1 to 7 crystallise out until the Fe_2O_3–Al_2O_3 ratio in the solution has been increased to 3 to 5.

(4) That when the Fe_2O_3,Al_2O_3 ratio has been increased until it has become 3 to 5, mixed crystals of this latter ratio crystallise out, producing a further increase in the Fe_2O_3,Al_2O_3 ratio until at about 1370° it has become 4 to 4.

(5) That the aluminates in which part of the Al_2O_3 is replaced by Fe_2O_3 are capable of holding in solid solution less calcium oxide than the pure aluminates.

The experiments described suggested a possible explanation of the general formation of many minerals which apparently consist of mixed crystals formed in a slowly cooling magma.

C. M. M.

57. The System Lime–Alumina–Silica; (and its Relation to Blast-furnace Slags and Portland Cement). B. NEUMANN (*Stahl u. Eisen*, 1918, **38**, 953; from *J. Soc. Chem. Ind.*, 1918, **37**, 770A).—The author reviewed the present state of knowledge in regard to the ternary system $CaO–Al_2O_3–SiO_2$.

Portland cements made from pure materials and burned at a sufficiently high temperature would consist solely of $3CaO,SiO_2$, $3CaO,Al_2O_3$, and $2CaO,SiO_2$.

The natural impurities resulted in free lime or free $5CaO,3Al_2O_3$ being present in commercial cements, together with small quantities of magnesia, iron oxide, etc.

The following summary of the compounds formed in the production of Portland cement was given:—

Cement.	Percentage composition of raw materials.	Burning temp.	Constituents in finished cement.
Chemically pure cement.	$CaO = 68·4$ $Al_2O_3 = 8·0$ $SiO_2 = 23·6$	1650°	$2CaO,SiO_2$ $3CaO,SiO_2$ $3CaO,Al_2O_3$
White cement.	$CaO = 6·62$ $Al_2O_3 = 6·4$ $SiO_2 = 25·0$ MgO,Fe_2O_3, Na_2O,K_2O = 2·4	1525°	$2CaO,SiO_2$ $3CaO,SiO_2$ $3CaO,Al_2O_3$ Trace CaO
Commercial (grey) cement.	$CaO = 63·2$ $Al_2O_3 = 7·7$ $SiO_2 = 22·4$ MgO,Fe_2O_3, Na_2O,K_2O,SiO_2 = 6·7	1425°	$2CaO,SiO_2$ $3CaO,SiO_2$ $3CaO,Al_2O_3$ Trace CaO $CaO,3Al_2O_3$ and ferrite

If the clinker was insufficiently burned, there would be a deficiency of $3CaO,SiO_2$.

The temperature of formation of tricalcium silicate was about 1700°; calcium aluminate appeared to act as a flux, allowing the $3CaO,SiO_2$ to form at a lower temperature.

A. M. J.

58. Hydrothermal Formation of Minerals (Silicates). W. J. MÜLLER and J. KOENIGSBERGER (*Zeitsch. anorg. Chem.*, 1918, **104**, 1).—Investigations have been made as to the products formed when mixtures containing K_2O, Al_2O_3, SiO_2, and water are heated together under pressure for varying times at temperatures from 100—440° in the presence or absence of carbon dioxide. The results obtained in the presence of carbon dioxide agree better with the observed order of succession of minerals in clefts and cavities in nature than those in the absence of carbon dioxide. Below 360°, *potassium felspar* is not formed. In the presence of carbon dioxide, only quartz is stable at 310°, but at higher temperatures aluminosilicates begin to appear. In the absence of carbon dioxide, *zeolites* are formed at 100°, but apparently their limit of stability is reached below 300°. However, the opinion is expressed that in no case was a true equilibrium obtained in the experiments below 400°. Besides the minerals already mentioned, *leucite*, *potassium nepheline*, and *pectolite* were identified among the products. C. M. M.

III.—Lampworked and General Scientific Apparatus

59. A Special Stopcock for Dropping Liquids arranged for Equalising the Pressure Above and Below the Outlet of the Stopcock. H. L. FISHER (*J. Ind. Eng. Chem.*, 1918, **10**, 1014).—When dropping liquids into a vessel in which the pressure is either above or below the atmospheric, it is usual to connect the top of the reservoir to the container by means of an external tube. In this new apparatus connection is made by means of an annular groove in the key of the stopcock, so that no matter which position the key occupies, there is always communication between the atmosphere in the lower flask and the atmosphere in the upper reservoir (Fig. 2). The outer arm of the stopcock is extended until it opens above the liquid in the container. The liquid, passing downwards, enters at an aperture in the lower part of this extended arm, and is delivered through a small glass tube sealed in at this opening. Below the barrel of the stopcock the two tubes continue to run concentrically, the outer, or air-communicating, tube ending a little above the end of the inner, or liquid, tube. S. E.

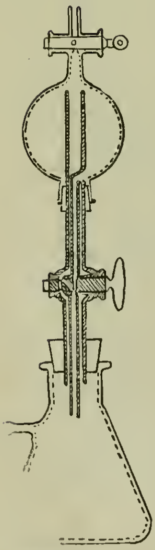


FIG 2.

60. Absorption Pipettes. E. van Alatine (*J. Ind. Eng. Chem.*, 1919, **11**, 51).—When using the Parr carbon apparatus, it seems desirable to have an absorption bulb which is effective and rapid, but which does not contain glass beads or rods. The apparatus, as shown in Fig. 3, has been designed to meet this need, and is of a size suitable for absorbing up to 100 c.c. of carbon dioxide from 100 to 200 c.c. of air. If absorption from a smaller volume of air is made, a pipette with smaller bulbs, *A* and *B*, and a smaller capillary at *E* should be used. If absorption from a larger volume of air is to be made, then *A*, *C*, and *D* should be larger, but *B* should not be changed.

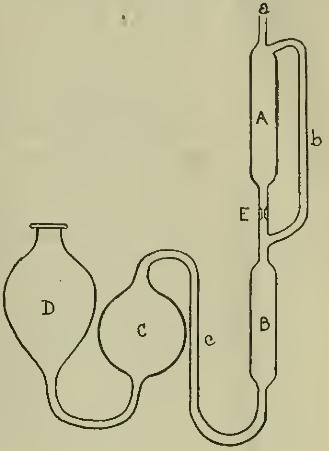


Fig. 3.

When the gas enters at *A*, it quickly forces the liquid from the tube *b* and the bulb *B*, through the tube *c*, into the bulb *C*. Such gas as still remains to be forced into the pipette must pass through the bulb *B*, the sides of which are kept wet by the liquid dripping slowly through the capillary *E*. By the time that *A* is half emptied, all the gas has been forced out of the Parr apparatus. When the bulb *A* has completely been emptied through the capillary *E*, some of the gas will have passed from *B* to *A* through the tube *b*, but most of it will have been trapped in the bulb *C* by the falling liquid filling the bend in the tube *c*. As this gas is drawn back to the Parr apparatus, it must bubble through this liquid in the bend of *c*.

Although it is not necessary to shake the pipette, absorption is, according to the author, as rapid as it is in a bead-filled apparatus.

S. E.

61. New Reflux Condenser. J. J. Bajda (*J. Ind. Eng. Chem.*, 1919, **11**, 52).—In a common type of reflux condenser, the hot vapours enter at the colder end of the cooling chamber, and, on condensing, block up the exit tube until the increasing weight of liquid forces its way down the tube and spurts back into the receiver. To overcome these undesirable features, the hot vapour is led by a side-tube, 2 (Fig. 4), to the top of the condenser and into the top end

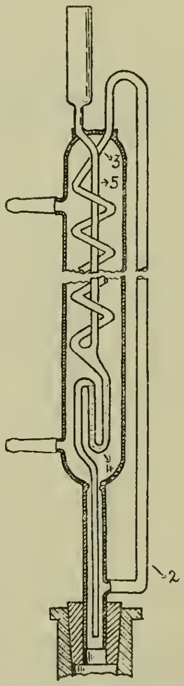


Fig. 4.

of the condensing coil, 3. The condensed liquid flows through the trap 4 back to the receiver in a steady stream. Any tendency to disturb the balance of the liquid in the trap finds an outlet through the central tube 5. The flow of the cooling water in a direction opposite to that of the condensed liquid diminishes the strain put on the glass. S. E.

62. The Limits of Separation by Fractional Distillation. A New Still-head.

S. F. Dufton (*J. Soc. Chem. Ind.*, 1919, **38**, 451).—The new still-head consists of two glass tubes, one inside the other, the inner one having its ends sealed up, and the annulus between the two tubes containing a spiral of wire. The condensed liquid seals the wire spiral to the two tubes, and thus causes the ascending vapours to pass along a long spiral track. Since the volume of liquid returning to the flask is much greater at the bottom of the still than it is at the top, it is advisable to have the wire wound on cores of decreasing diameters, as shown in Fig. 5, using thicker wires as the width of the annular space increases.

With such a still-head, it is claimed that almost perfect separation of such liquids as benzene, toluene, and xylene from their mixtures can be obtained. S. E.

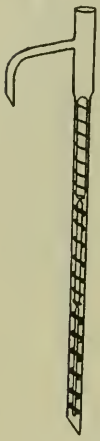


Fig. 5.

63. Apparatus for the Continuous Testing of Gases, with Special Reference to Acid or Alkaline Constituents.

C. A. King (*J. Soc. Chem. Ind.*, 1919, **38**, 33T).—A current of the gas to be tested is passed upwards through a small absorption chamber provided with projections inwards from the wall (Fig. 6). The washing and indicating solution is dropped steadily into a U-tube, which is connected to the upper end of the absorption chamber. The solution drains away from the lower end of the absorption chamber through another U-tube, in which any change of colour of the solution can be noted.

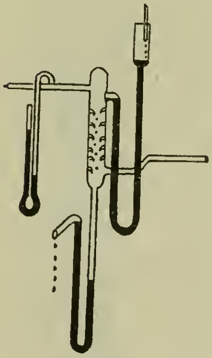


Fig. 6.

When a supply of gas is being tested for ammonia, the indicator used is a solution of methyl-red with just sufficient acid added to develop the true red colour. If ammonia is present, it changes to yellow, the change being readily observed even in artificial light. S. E.

64. Glass-cutting Tool. H. H. Parker (*J. Amer. Chem. Soc.*, 1918, **40**, 195).—A description is given of an instrument which resembles in appearance a gas-heated soldering bit. The object of the instrument is to replace the heated end of a file, which is often used to lead cracks in glass. The paper contains three illustrations of the apparatus, and photographs of work carried out with it. J. D. C.

65. An Improved Automatic Burette. G. J. Hough (*J. Ind. Eng. Chem.*, 1919, **11**, 229).—The burette illustrated in Fig. 7 was devised for use with bottles containing stock solutions. Its advantages are that it requires no bracket to support it, and that it can be quickly removed and cleaned ready for use with another solution.

The base of the burette consists of a glass tube, *a*, passing to the bottom of the bottle containing the solution. This is surrounded by a wider tube, which passes through the rubber stopper fitted into the neck of the bottle. To the side-tube, *c*, is attached a pressure bulb, and *d* is closed up by the thumb while pumping air into the reservoir. The hole, *h*, in the outer jacket, which should be above the level of the liquid, serves to equalise the pressure in the reservoir.

S. E.

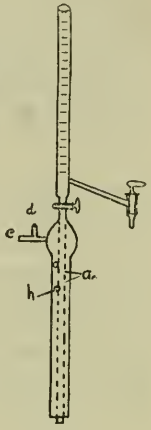


Fig. 7.

66. On the Lags of Thermometers with Spherical and Cylindrical Bulbs in a Medium whose Temperature is Changing at a Constant Rate. A. R. McLeod (*Phil. Mag.*, 1919, [vi], **217**, 134).—The lag of a thermometer situated in a medium the temperature of which is changing is of practical interest in the case of ascending aeroplanes and balloons. The medium in this case is the atmosphere, but application might also be made to the case where the variable temperature of any other medium is to be determined by a thermometer as a function of the time. Expressions are given for the steady values of the lags for spherical and cylindrical bulbs when the surface conductivity is finite, and for the lags at any instant when the surface conductivity is infinite. In a uniform temperature gradient, the lag varies almost inversely as the conductivity of the fluid filling the thermometer. Numerical results are given for mercury and alcohol in spherical and cylindrical bulbs. These calculated results show that for spherical bulbs of mercury and alcohol giving the same volume expansion the lags are about the same. With the same thermometric substance the lag is less for cylinders 10 cm. long than for spheres giving the same volume expansion, and it is less for a cylinder of alcohol than it is for a cylinder of mercury. S. E.

IV.—Decorated Glass.

67. Production of Metallic Decorative Coatings on Glass. (*Chem.-Zeit.*, 1903, **27**, 1138).—It is stated to be impossible to obtain a non-transmitting, and therefore perfectly reflecting, film by the ordinary staining process. If, however, the glass is covered with the metallic oxide and heated alternately in a reducing and oxidising atmosphere three or four times, such a film is produced. This film is so bound to the glass that it is only attacked by aqua regia. J. R. C.

68. Coloration Method. B. D. Avis (U.S. Patent 1277172, 1918; from *J. Soc. Chem. Ind.*, 1919, **38**, 22a).—The method described is an improvement in the process described in the U.S. patent 933522. The surface to be coated is covered with an ammoniacal solution of dimercuric ammonium nitrate or an alkaline alcoholic solution of a double mercury alkali salt, and the double salt is precipitated by evaporation of the ammonia or alcohol. It is stated that glass, porcelain, metal, wood, paper, etc., can be coloured by this method. The transparency of glass is not destroyed by the coloration.

S. E.

V.—Optics and Optical Instruments.

69. The Optical Properties of Vitreous Silica. J. W. Gifford and W. A. Shenstone (*Proc. Roy. Soc.*, 1904, **73**, 201).—The composition of vitreous silica is not liable to variations such as occur in two meltings of the same glass; it is not attacked by most reagents, and the supply is not limited like that of fluorite. It can be regarded, therefore, as a standard glass. A prism of this substance was prepared by the authors from one melting, and also a compound prism was made by a workman from four different melts. This last prism was found to be perfectly homogeneous, differing in this way from a prism made from four pieces of optical glass from the same melt. The refractive indices of the silica for wave-lengths ranging from 7950 to 1850 Å.U. were tabulated. For the D-line the value is 1·4584772. The dispersion, ν, is 67·920, as compared with 95·493 for fluorite and 70·048 for quartz.

J. R. C.

70. Tools for Grinding Glass of Refractive Index 1·523. W. J. Druiff (*Optician*, 1918, **55**, 177).—The radii of curvature, r, of lens-grinding tools are evaluated by the formula $r=M/D(\mu-1)$, where M is 1 metre, D the dioptric power, and μ the refractive index. The values of r for powers ranging from 0·12 to 2,800 were set out both in millimetres and inches. J. R. C.

71. The Field of a Prism. A. WHITWELL and T. CHAUNDY (*Optician*, 1918, **56**, 93, 143, 209).—A continuation of a series of articles on the behaviour of prisms (*cp.* Vol. II, Abstr. No. 100). The question of the field delimited by the various prisms was considered. In the first section the real and "ghost" images produced by rays parallel to the base of a right-angled isosceles prism were discussed, and subsequently the more general case of rays which are not so parallel. The consideration of oblique rays introduces the possibility of total internal reflections at the triangular faces, as well as at the rectangular ones, so the "equivalent prism" system was extended to include these reflections. The overlapping of the true and ghost images was treated briefly in the third section, and the manner in which any ray of a ghost image could be prevented from emerging. The latter was done by the insertion of stops of convenient size at suitable positions. J. R. C.

72. A Method of Testing Right-angled Prisms. S. D. CHALMERS and H. S. RYLAND (*Trans. Optical Soc.*, 1904—5, 34).—A beam of light is allowed to fall on the hypotenuse of the prism, part being internally reflected by one of the faces including the angle and part by the other. If the right angle be perfect, the two parts will return parallel to each other and to their original direction. The authors gave practical details of this test, and stated that an error of less than two seconds is recognisable. The same principle could also be used for testing plane parallel surfaces. J. R. C.

73. Some Uses of Cylindrical Lens Systems, including Rotation of Images. G. J. BURCH (*Proc. Roy. Soc.*, 1904, **73**, 281).—Stokes showed that when two lenses are placed in contact with their axes of curvature at right angles, the combination acts as a spherical lens, and the formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ holds for it. If the lenses are not in contact, however, there is only one pair of conjugate points at which a real object will give a real image. Such a system may be employed for comparing by photography curves plotted to different scales, or for increasing or diminishing the ordinates of a curve the scale of which is unsuitable. The appearances presented by the cylindrical telescope and cylindrical microscope are also described. In these cases, the axes of curvature of the lenses are parallel. The telescope is particularly useful in that it can be used to rotate an image formed by polarised light without affecting the polarisation of the light. J. R. C.

74. A Chart for finding the Number of Lenses in, and Size of a Block. H. LEE (*Trans. Optical Soc.*, 1918, **19**, 165).—Formulæ for finding the number of lenses in a block have been given. The practical cases are those in which there are one or three lenses in the centre. Charts are constructed for these two cases, so that, given the diameter of the lenses and the radius of curvature, the number of lenses which may be placed on a block of given radius, or, alternatively, the radius of the block required to contain a number of lenses, can be determined immediately. The charts are easily understood. J. R. C.

75. Charts for assisting in the Selection of suitable Glasses for Cemented Doublets. T. Smith (*Trans. Optical Soc.*, 1918, **19**, 169).—The charts described in this paper are intended to serve as a guide to a computer in selecting a pair of glasses for any purpose. Objectives of the type considered can be calculated from expressions for the first order aberrations when thicknesses are neglected. The aberrations of such thin lenses are determined by three quantities, which depend on the relative powers of the two component lenses and on their refractive indices. To enable a two-dimensional diagram to be drawn, one of these quantities must be fixed, and since many lens combinations include a dense flint of refractive index about 1·62, one chart has this as the fixed quantity. The refractive index of the other glass is taken as abscissa, and the ordinate is the logarithm of the ratio of the powers. This chart is used in conjunction with a second, which has the same abscissa and the logarithm of ν as the ordinate. By substituting for this second chart another diagram in which the ordinates are changed, any required amount of chromatic aberration may be introduced without affecting the spherical corrections. By the use of such charts, much time can be saved in calculating simple cemented objectives, since it is possible to ascertain beforehand that the glasses selected will be the most suitable of those that are available. After the selection has been made, the proper curvatures for the surfaces of the new lens will then be found in the usual way. J. R. C.

76. The Prevention of Film in enclosed Optical Instruments. H. S. Ryland (*Trans. Optical Soc.*, 1918, **19**, 178).—In every type of enclosed optical instrument, instances of "film" will be found. The following precautions when taken have been ascertained to eliminate film: (1) No japan or bitumen-black to be used on interior surfaces. (2) No pitch or beeswax to be used within the case. (3) All interior surfaces must be thoroughly cleaned and freed from animal matter, such as finger-marks. In the case of aluminium or other porous metals, heat treatment is necessary after machining to remove all traces of grease. (4) The lenses and prisms after ordinary cleaning must be dipped in hot running water with a pair of tweezers, and wiped dry with clean linen. (5) After washing the linen used for cleaning purposes, it must be well rinsed in running hot water until all trace of soap has gone. (6) Dust must be removed with a clean camel-hair brush and not by blowing. (7) The linen used for cleaning must be used in such a way that no part of it which has been touched by the fingers is brought into contact with the glass surface. (8) All surfaces must be well polished.

In the discussion which followed the paper, J. W. French laid stress on the necessity for the efficient desiccation of optical instruments and scrupulous cleanliness in all optical work. C. Beck stated that there is evidence to show that film does not appear inside optical instruments except in the presence of moisture; for example, it is not met with inside submarine periscopes, which are filled with absolutely dry air and hermetically sealed. J. R. C.

77. Astigmatism: Interchangeability of Planes of Stop and Object. T. Chaundy (*Trans. Optical Soc.*, 1918, **20**, 11).—A beam of light from a source near the axis of the system is supposed to pass through a co-axial optical system. The beam is restricted to be of small angle by an axial stop. The paper dealt with the astigmatism of the image and with the conditions under which an interchange of the planes of the source and the stop leave the astigmatism unaffected. The problem was analytically discussed by a method of line co-ordinates which supposes that the co-ordinates of a typical ray after emergence from the instrument are expressed as functions of the co-ordinates of the ray before incidence. The condition of interchangeability was derived, and the case in which the incident beam is parallel received special consideration. J. R. C.

78. Stray Light in Optical Instruments. L. C. Martin (*Optician*, 1918, **55**, 239).—The presence of this unwanted light is not very easily recognised in an ordinary examination of the instrument, but the author described an arrangement which easily reveals its presence. A black disc, 2 feet in diameter, is pasted on a piece of tissue paper, 6 feet square, which is placed in front of a window. If the disc is examined by the instrument to be tested, no light should be transmitted through the eyepiece. Some stray light is introduced by double reflections at air–glass surfaces, and the author advocates the cementing of components, where possible. Another source of stray light is the ring of dirt sometimes left round the edges of the objective. This scattered light could be eliminated by internally stopping down the objective. The performances of an English prism binocular, a Zeiss binocular, and a Galilean binocular were compared by means of photographs. In the Zeiss instrument, reflected light from the walls of the tube had been controlled by the provision of a series of diaphragms mounted in the tube, so that no reflected light could reach the eye.
J. R. C.

79. Micrometer Microscopes. A. W. Gray (*Optician*, 1918, **55**, 217, 227, 242, 253).—The first article dealt with some errors affecting measuring microscopes. The most important corrections are necessitated by the deviations from the nominal value of a division and other constructional errors. Temperature changes may cause variations in magnification by thermal expansion of the screw, or the microscope lenses, or by altering the refractivity of the media traversed by the light. Serious errors may also be caused by failure to focus accurately. Another possible source of trouble may long evade detection. Any holes in the surfaces of the thrust bearings may harbour minute grains of dust, which in time work between the rubbing surfaces and produce more or less periodic irregularities. When high accuracy is demanded, the screw errors should be investigated periodically.

Methods of applying corrections to a group of micrometers were considered in the second article. For this purpose, the author has developed a method which requires little expenditure of labour after the microscopes have once been calibrated. It is a simplification of that employed by the International Bureau of Weights and Measures in measuring the national prototype meters. The method was described and an example given.

The third and fourth sections were devoted to a description of the determination of the corrections of micrometer microscopes. The method employed is a graphical one, and is very sensitive.

J. R. C.

80. The Examination of a Microscope Objective. K. Strehl (*Zeitsch. Instrumentenkunde*, 1905, **25**, 3).—The author treats of the wave surface transmitted by the objective, and the effects of spherical and chromatic aberration are discussed. The paper is too mathematical to be abstracted. J. R. C.

81. A New Construction for Bodies of Binoculars. (*Optician*, 1919, **56**, 247).—A detailed description of a method of manufacture of the bodies of binocular or monocular glasses. Hitherto these have been made, usually, by casting aluminium, but by the new method any suitable sheet metal can be used.

J. R. C.

82. Aeronautical Sighting and Range Finding Apparatus. (*Optician*, 1919, **56**, 226).—The instrument described furnishes the means for determining the distances and positions of terrestrial objects from aeroplanes during flight, and by it also the speed of the machine relative to the ground can be accurately ascertained. Numerous diagrams are given to illustrate the principles set out. J. R. C.

83. Improvements in Range Finders. (*Optician*, 1919, **56**, 216).—A description of a range-finder more especially adapted for the use of anti-aircraft guns. It is assumed that the height of an enemy aircraft has already been given by some other station, and the function of the instrument is to determine the angular elevation. The article is diagrammatically illustrated. J. R. C.

84. Testing of Materials at the Optical Institute of C. P. Goerz. G Berndt (*Deutsch. Mech. Zeit.*, 1918, **99**, 109, 121).—In the first section, after dwelling on the advantages of having instruments for testing the raw materials used in the construction of scientific instruments, the author discusses the form of the elasticity curve for metals after the limit of elasticity has been reached and Hooke's law has ceased to be valid. All the machines described subsequently are specially intended for testing metals, but where the tests are applicable they can be used for the examination of glass also. A hydraulic machine for tension and compression fracture tests, a torsion machine, a Brinell press, and an arrangement for testing resistance to fracture when struck are described. The first three are of the usual type, and the last consists essentially of a weighted pendulum, the weight, at the bottom of its swing, hitting a plate of the material under test. The surfaces resulting from the fracture of metals are illustrated and discussed. J. R. C.

85. The Optical Determination of Stresses in Aeroplane Spars. A. R. Low (*Engineering*, 1919, **107,** 234).—A scale model of a standard pattern of aeroplane spar was made, using xylonite for the spars and steel for the struts and wires. The spars were loaded, and the stresses in them determined by using crossed Nicols. The numerical values of the stresses were obtained by loading a simple tension test-piece until the same colour was observed as with the loaded spar. The discrepancies between the observed and calculated values were often considerable, especially at high loads. S. E.

VI.—Illumination and Illuminating Ware.

86. The Use of Inert Gases in Electric Incandescent Lamps (Brit. Pat. No. **112264**). SIEMENS & HALSKE AKT.-GES., Nov. 22nd, 1917, No. 17211. Convention date, Dec. 29th, 1916. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—A carbon-filament lamp is filled with an inert rare gas, such as argon, practically free from traces of nitrogen or other harmful gas. Other inert substances, such as mercury vapour, may be present. Increased life and efficiency are obtained. H. G. C.

87. Thorium Pyrophosphate (Brit. Pat. No. **112380**). WELSBACH CO., GLOUCESTER, NEW JERSEY, U.S.A. ([Assignees of M. A. Goltz, Winona, Minnesota, U.S.A.], June 14th, 1917, No. 8550. Convention date, Feb. 28th, 1917).—The product obtained by decomposing monazite sand with sulphuric acid is heated to a sufficient degree to convert some or all of the free phosphoric acid into pyrophosphoric acid. On treating the mass with water, a precipitate of thorium pyrophosphate is obtained. H. G. C.

88. A New Illuminator for Microscopes. Alexander Silverman (*J. Ind. Eng. Chem.*, 1918, **10**, 1013).—In this new illuminator three iris-like fingers fasten a circular lampholder to the objective of the microscope. The lamp used is a 9 volt, 0·7 ampere unit with a blue or daylight glass. Experiments show that the heat given off by such a lamp is insufficient to cause any harmful effect on the objective, even although it be left running continuously for some considerable time. A shutter may at times prove desirable to cut off the light from one-half of the circular source. To answer this purpose, a dull black disc which is attached to the holder may be brought over so as to cover up half of the lamp. Details are sometimes visible when so illuminated, but are quite obscured when the whole lamp is bare. S. E.

89. Street Lighting Developments at Oxford. (*Electrician*, 1919, **82**, 109).—The holophane refractor lantern which has recently been installed in Oxford streets consists of two distinct prismatic pieces fitting closely inside each other, and thus modifying the natural distribution of the light. Although made up of prismatic elements, the interior and exterior of the lantern are quite smooth, and thus admit of easy cleaning. These lamps give a fairly uniform distribution of light, and also eliminate glare owing to the diffusion of the light on passing through the refracting surfaces. S. E.

90. Influence of Quality of Gas and Other Factors on the Efficiency of Gas-mantle Lamps. R. S. McBride, W. A. Dunkley, E. C. Crittenden, and A. H. Taylor (*U.S. Bureau of Standards*, Tech. Paper 110, 1918).—The paper is a report of a part of a general investigation to determine the relative usefulness of gases of different heating values for mantle lighting, cooking, water heating, etc.

Experiments were carried out with various types of upright and inverted incandescent mantle burners, and the gases employed in the investigation comprised carburetted water-gas of about 665 B.Th.U. and 565 B.Th.U. per cub. ft., coal-gas of about 565 B.Th.U. per cub. ft., some specially enriched gases of higher calorific value, and natural gas of calorific value 1120 B.Th.U. per cub. ft. The chief conclusions drawn were:—(1) The inverted burners show no difference in efficiency with lean water-gas with either adjustment; (2) upright burners have a higher efficiency with lean water-gas than with town gas, both at maximum efficiency adjustment and at maximum candle-powder adjustment; (3) the upright burners similarly show a distinct advantage in the use of the benzol-enriched gas as compared with ordinary town gas; (4) with all types of burners there is a small advantage gained by the use of water-gas rather than of coal-gas of the same heating value, except in some cases at very low pressures.

Experiments involving alterations of gas quality led to the conclusion that if a lamp is adjusted for maximum candle-power, an increase in the heat value of the gas supplied produces a decrease of efficiency, and *vice versâ*. It was concluded that the usefulness of a uniform quality of coal-gas of 550 to 575 B.Th.U. per cub. ft. increased or decreased with a corresponding change in the calorific value of the gas. C. M. M.

VII. Fuels, Refractories, and Furnaces.

91. Methane. W. Malisoff and G. Egloff (*J. Phys. Chem.* 1918, **22**, 529).—This paper contains a summary from all sources of the investigations which have been carried out on methane. It is pointed out that the consumption of natural gas in America in 1917 reached the figure of 900,000,000,000 cub. ft., this gas averaging 78·2 per cent. of methane. C. M. M.

92. Theory of Water-gas Formation. Gwosdz (*Zeitsch. angew. Chem.*, 1918, **31**, 137).—The author made investigations to ascertain the parts played in water-gas formation by the supposed primary reactions:—

$$(1)\ C + H_2O = CO + H_2 \text{ and } (2)\ C + 2H_2O = CO_2 + 2H_2,$$

and the secondary reactions:—

$$(3)\ C + CO_2 = 2CO \text{ and } (4)\ CO + H_2O = CO_2 + H_2.$$

Superheated steam was passed over various forms of heated carbon, and the composition of the issuing gases was determined. The speed of the current of steam varied, and the temperatures also varied from 855° down to 560°. It was found that natural forms of carbon containing ash in appreciable quantities behaved in a very different way from purified carbon almost free from ash. Thus with gas coke (8·5 per cent. ash) and wood charcoal (1·4 per cent. ash), a considerable proportion of carbon dioxide was always formed (up to 29 per cent.). On the other hand, lamp carbon (0·1 per cent. ash) at temperatures down to 600° gave mixtures closely resembling water-gas as manufactured. Even at 560° the mixture obtained was:—CO_2, 8·6 per cent.; CO, 39·5 per cent.; H_2, 40·0 per cent.; residue, 11·9 per cent. It was concluded that reaction (2) cannot be primary, because reaction (3) is known to be too sluggish to account for the formation of the high percentage of carbon monoxide found at these low temperatures. Further, that reaction (1) is the primary reaction of water-gas formation, and that the carbon monoxide formed reacts with the excess of steam, tending to establish the water-gas equilibrium, and that this reaction is catalytically influenced by the finely divided ash in the carbon. C. M. M.

93. Carbonisation of Lignites. E. Stansfield and R. E. Gilmore (*Trans. Roy. Soc. Canada*, 1917–18, **11**, 85).—Laboratory tests were carried out on a sample of lignite having a gross calorific value 4260 calories, moisture 31·8 per cent., ash 5·2 per cent., volatile matter 28·9 per cent., fixed carbon 34·1 per cent. The calorific value of the dried lignite was 6260 calories.

Five sets of carbonisation experiments on the material as received were carried out. (1) Ordinary carbonisation between 200° and 700°. The loss of volatile matter was slight up to 300°, increased rapidly up to 600°, and was practically constant by 700°. The calorific power of the residue increased to a maximum (7530 calories) at 550—600°, and then decreased. (2) With slow carbonisation similar results were obtained, except that for any given final temperature the loss of volatile matter was less than with more rapid carbonisation. (3) With vacuum carbonisation (25 mm.), the volatile matter given off was greater than at ordinary pressures, the calorific value of the residue was practically the same up to 350°, but above that temperature it was less (for example, 7365 calories at 600°). (4) With carbonisation in the presence of steam, up to about 450°, results were obtained similar to those in the previous tests, but above that temperature the results varied. It was concluded that 450° is the maximum temperature for satisfactory carbonisation in the presence of steam. In this series the calorific value of the residue was in all cases slightly lower than in the vacuum series. (5) Carbonisation under pressure gave results closely resembling those of the vacuum series, but the calorific values of the residues were higher than in any other series, the maximum being 7640 calories at 550°.

It was concluded that a temperature about 600° is the most suitable for carbonisation. J. D. C.

94. Fuel-economisers. (Brit. Pat. No. **111393**). W. Sharp (February 5th, 1917, No. 1790).—Irregularly-shaped porous refractory blocks with roughened surfaces, for use in combination with coal or coke in open fireplaces, are made of fire-clay or common clay together with slaked lime and sand, to which are added coarse sawdust or crushed coke, the whole being intimately mixed, rendered plastic by the addition of water, moulded, and cut into the required shapes, air-dried, and burnt in an open fireplace. H. G. C.

95. The Manufacture of Refractory Materials for Glass Works Construction. R. H. Minton (*Trans. Amer. Cer. Soc.*, 1906, **8**, 353).—In the author's view, the main essentials for a good tank block are high refractoriness, resistance to the fluxing action of lime, salt-cake, etc., used in making the glass, resistance to the wearing action of the moving glass, and non-conductivity. Extreme fineness of grain of the clay is to be avoided, as this causes fluxing at lower temperatures than with coarser grain.

Again, coarse grains insure greater resistance to heat, but decrease the resistance to erosion. The block must be well burned to reduce shrinkage; it must be dense to resist fluxing and wearing action, but not so dense as to induce cracking. These requirements are conflicting, and experience must decide the correct proportions in which to mix the materials required. The processes of manufacture of the blocks were described. J. R. C.

96. The Calculation of the "Rational Analysis" of Clays.

HENRY S. WASHINGTON (*J. Amer. Cer. Soc.*, 1918, **1**, 405).—By far the greater number of clays of any notable commercial value contain the four minerals kaolin, quartz, felspar, and mica. As each of these influences the "burning" and other properties of a clay and of the finished products, it is of importance to be able to estimate the relative amounts of each present in any given clay, so that the proper mixtures may be made or the proper temperature and other conditions may be controlled.

The "rational" analysis aims at the estimation of the amounts of the different minerals that are present in a clay, and seeks to attain its object by treatment of the clay with various strong reagents, particularly hydrochloric and sulphuric acids and alkali hydroxides. Following Mellor, the essential features of the "rational" analysis are: digestion of the clay with hot concentrated sulphuric acid and subsequent washing, alternatively with alkali and hydrochloric acid, to remove the "clay substance." This may be preceded by treatment with hot alkali to remove soluble silica, or with dilute hydrochloric acid to remove the carbonates, and it may be followed by evaporation of the residue with hydrofluoric acid to remove quartz and other silica, and determination of alumina, which is used as a basis for the calculation of the felspar present. Factors that will seriously influence the results are: the chemical composition of the mineral treated, the size of the grain, the concentration of the reagent, the length of time during which the material is treated, the temperature at which the mixture is treated, and whether this is attained suddenly or gradually or is uniform or varied during treatment. One can only consider, then, that the methods of "rational" analysis can furnish little but approximate and uncertain, and probably more or less erroneous and misleading, information. It would seem better, therefore, to call such an analysis "modal," as it aims at determining the "mode" or universal composition.

In contrast with the uncertainties of the "rational" analysis, the "ultimate," or what is better called the "chemical," analysis can be carried out with ease and great accuracy and its results stated in terms of the constituent oxides, may, the author believes, be readily reduced to mineralogical terms by a simple process of calculation that will yield information as to the mineral composition of a clay far more accurate and certain than the information furnished by the usual "rational" analysis, even when the latter is properly executed and the calculations are correctly made.

The paper suggests a simple and expeditious method of calculating the mineral composition of a mixture of silicates from the chemical analysis, and describes a modification adapted to the mineralogical characters of clays. Stated briefly, the principle consists in utilising our knowledge of the various molecules which the constituent oxides are capable of forming, and in considering the minerals present in the rock or clay as made up of such molecules, the actual minerals into which the molecules combine being dependent on the conditions and being in accordance with our knowledge of the occurrence of minerals in rocks.

The chemical ("ultimate") composition of a clay is expressed as made up of silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3), magnesia (MgO), lime (CaO), potash (K_2O), soda (Na_2O), water (H_2O), with sometimes small, but possibly notable, amounts of titanium dioxide (TiO_2) and carbon dioxide (CO_2), and very small and negligible amounts of other constituents. In mineralogical or "modal" composition ("rational"), all clays are essentially mixtures of kaolin ($Al_2O_3,2SiO_2,2H_2O$), and, expressed below by the symbol Kl, quartz = Q, and the felspars, orthoclase = Or ($K_2O,Al_2O_3,6SiO_2$), albite = Ab ($Na_2O,Al_2O_3,6SiO_2$), and anorthite = An ($CaO,Al_2O_3,2SiO_2$), and, in some clays, small amounts of muscovite = Mu ($K_2O,2H_2O,3Al_2O_3,6SiO_2$). The problem is to express the chemical composition of a clay in the terms of the minerals kaolinite, quartz, and the three felspars.

From the analysis of a mineral, the formula is found by reducing the constituents to molecules and finding the ratios of these. Suppose that the composition by chemical analysis is:—

	Percentage composition.	Molecular composition.
SiO_2	63·36	1·056
Al_2O_3	23·76	0·233
Fe_2O_3	0·52	0·003
CaO	0·69	0·012
Na_2O	0·97	0·016
K_2O..................	1·63	0·017
H_2O..................	9·07	0·504

Here (assuming the absence of calcite) the lime (CaO) forms part of residual anorthite ($CaO,Al_2O_3,2SiO_2$), or possibly one of the calcic zeolites, which contain hydrated anorthite molecules. The soda (Na_2O) forms part of residual albite ($Na_2O,Al_2O_3,6SiO_2$), or possibly may form part of sodic zeolite, in which hydrated albite or nephelite molecules are present, the difference in silica content of which is of negligible moment. The ferric oxide may be assumed to be present as limonite (Fe_2O_3,H_2O), the most common of the hydrated ferric oxides. The calculation is briefly done thus: After calculating the orthoclase, albite, and anorthite, the remaining alumina serves as a basis for calculating the kaolinite; the ferric oxide is the basis for calculating limonite; the silica remaining from the orthoclase, albite, anorthite, and kaolinite is the quartz, and the water remaining from the kaolinite and limonite is moisture. The calculation is represented thus:—

Orthoclase = 556 × 0·017 = 9·45 per cent.
Albite = 524 × 0·016 = 8·33 ,,
Anorthite = 278 × 0·012 = 3·34 ,,
Kaolinite = 258 × 0·188[1] = 48·50 ,,
Limonite = 178 × 0·003 = 0·53 ,,
Quartz = 60 × 0·458[2] = 27·48 ,,
Moisture = 18 × 0·125[3] = 2·25 ,,
99·88

[1] 0·188 = 0·233 − (0·017 + 0·016 + 0·012).
[2] 0·458 = 1·056 − [(6 × 0·017) + (6 × 0·016) + (2 × 0·012) + (2 × 0·188)].
[3] 0·125 = 0·504 − [(2 × 0·188) + 0·003].

If carbon dioxide is found, it is assumed to be present in calcite; an equivalent amount of CaO is allotted to the CO_2 for calcite, the calcite is then reckoned by multiplying the molecular number of CO_2 by 100, and the rest of the lime is calculated to anorthite, as above.

Magnesia (MgO) may be assumed to be present in chlorite, a complex mineral, or rather mineral group, into which biotite usually enters; but it is best treated on the assumption that it enters serpentine ($3MgO,2SiO_2,2H_2O$), the unit of calculation being one-third of the molecular number of the MgO present. Any error involved will be quite negligible.

Muscovite may be present, though in small amount. Its composition may be considered as a mixture of orthoclase, alumina, and water, so that the percentage amount in a clay cannot be calculated from a chemical analysis alone if orthoclase and kaolinite are present also. However, as orthoclase and muscovite have about the same fluxing effect, it will serve all practical purposes to calculate the potash of any muscovite present as orthoclase and the alumina as kaolinite, some of the excess silica being taken for this. It is obvious that the separate determination of potash and soda is necessary for the proper calculation of the felspars.

A table of "rational" and "chemical" analyses of clays is appended, which shows that these two modes of analysis do not generally agree; indeed, some of them are hopelessly incongruous, and, in the author's opinion, the so-called "rational" analysis is quite untrustworthy. C. M. M.

97. The Porosity and Volume Changes of Clay Fire-brick at Furnace Temperatures. George A. Loomis (*J. Amer. Cer. Soc.*, 1918, **1**, 384).—Failure to classify clay fire-bricks satisfactorily has, in the author's view, been due in part to the fact that clay refractories are used under such a variety of conditions. It is generally conceded, however, that refractoriness is a primary requisite of a fire-brick for general use. The other properties, such as ability to resist abrasion or the penetration of slags, may be said to be of secondary importance.

Of the several tests of refractoriness, the three which have been used the most are: the chemical analysis, which gives a theoretical indication of refractoriness, the direct determination of the so-called "softening point," and the determination by an actual "load test" of the ability of a fire-brick to resist deformation under loads at high temperatures. Another test, which has not been used very extensively in the case of fire-bricks, is the determination of the porosity and volume changes on heating the bricks to different temperatures. A decrease in porosity and volume indicates the progress toward vitrification. Over-firing is then indicated by an increase in porosity and by an increase in volume as the vesicular structure accompanying over-firing is developed. The value of this test is all the more evident when it is realised that the degree of vitrification, as shown by the changes in porosity, also represents the amount of softening which must necessarily take place in the process of vitrification. Marked softening of the mass of the brick means decreased resistance to deformation.

A study of the data obtained shows some interesting relationships between the porosity and volume changes and the results of the load tests. In nearly all cases of brick which successfully withstood the load test—showing a deformation of not more than 5·55 per cent.—there was comparatively little volume change by either expansion or contraction up to 1425°, whilst a considerable number of the bricks which failed in the load test showed very appreciable volume changes. Similarly, the porosity decrease in the case of bricks which passed the load test is not large, whilst many of those which failed show considerable decrease in porosity at some point below 1425°. In many cases, over-burning of the brick of poorer grade is distinctly evident from the volume and porosity changes. The sudden and more or less pronounced expansion at the lower temperatures of firing, in the case of some of the bricks, is certain evidence of over-burning, which was confirmed by the results in the load tests. An abrupt increase in porosity at the same or at a slightly higher temperature is usually noted in such cases. Invariably, such bricks failed in the load test. Bricks which showed either marked volume change or a considerable decrease in porosity also failed to withstand the load test. It would seem, then, that the volume and porosity changes of clay fire-bicks might serve in some measure as a criterion of their ability to withstand load at high temperatures. C. M. M.

98. The Tensile Strength of Raw Clays. H. Ries (*Trans. Amer. Cer. Soc.*, 1904, **6**, 79).—During the air shrinkage of a clay, the particles draw together into a close mass, and this air-dried body is hard enough to suggest that the grains must be tightly packed, if not interlocked. Equal sized grains are not capable of becoming packed into a dense, tight mass, but variation in grain size permits the pore space to be filled in. The tensile strengths of five clays, of different mechanical compositions, were determined.

Diameter of grains in mm.	Percentages of each grain size. Clay 1.	Clay 2.	Clay 3.	Clay 4.	Clay 5.
0·005—0·0001	87·96	30·645	22·00	44·00	59·00
0·01 —0·005	6·95	14·21	5·66	7·11	11·00
0·25 —0·01	3·00	5·585	26·55	24·35	14·70
0·5 —0·25	1·00	6·400	11·45	7·80	3·50
1·0 —0·5	—	42·95	33·44	16·35	11·40

Tensile Strengths in lb. per square inch.

Clay No. ...	1	2	3	4	5
	20	105	289	297	453

From this table it appears that an excessive amount of small clay particles or a large percentage of sand grains (1·0—0·5 mm.) weakens the strength of the air-dried clay. J. R. C.

99. The Measurement of Plasticity and Textile Strength.

E. C. Stover and J. Lindley (*Trans. Amer. Cer. Soc.*, 1905, 7, 397).—The apparatus used for determining plasticity consisted of a hollow brass tube 2 inches in diameter and 12 inches long, made conical at one end, and provided with a screw cap $\frac{7}{8}$ inch in diameter, to which brass collars with various sized holes could be secured. The clay to be tested was made into a roll and placed in the cylinder beneath a plunger, which was forced down until the clay was squeezed slowly through the hole in the bottom disc. A cord of clay thus hung down, finally breaking under its own weight. The more plastic the clay the greater the weight required to break the cord. The method gave uniform results.

In the tensile stress test the cross-breaking strain was measured, a cylinder being prepared, 3 inches long and ends 1 square inch in area, and the couple required to break it ascertained.

J. R. C.

100. The Occurrence of High-grade American Clays and the Possibilities of their Further Development.

H. Ries (*J. Amer. Cer. Soc.*, 1918, **1**, 446).—Before the Great War, clays from Central Europe, used in the manufacture of glass pots, graphite crucibles, enamels, etc., and the china and ball clays of England, were imported by the United States. Investigations, partly urged by war necessity, had, however, shown that the United States could supply satisfactory refractory clays of high bonding strength, suitable for fire-bricks, glass-pots, crucibles, etc., and that it has a considerable reserve of kaolins. A single clay may not have all the desired properties, but judicious blending of two or more clays may often yield a mixture having the desired properties. The high-grade clays were mostly located in the eastern half of the United States, whilst some clays of value occurred in the west; they had not been drawn upon by factories. Detailed results were promised in a bulletin of the United States Geological Survey.

A. M. J.

101. The Nature of the Air Content of Pugged Clays. H. Spurrier (*J. Amer. Cer. Soc.*, 1918, **1**, 585).—The author described a simple apparatus devised to secure any desired amount of the gas occluded in clay, and consisting of a large glass funnel inverted and equipped with a tube of 30 mm. internal diameter and suitably drawn out at both ends. The upper end is bent and capable of being connected to ordinary gas-collecting tubes. The funnel is immersed in water contained in a large iron bath; air is expelled from the tube, which then fills up with water. In an actual test, samples of pugged clays are slipped under the funnel, when the air contained in them rises into the tube and is collected, the clay being added until a sufficient quantity of gas is collected.

The following represents the composition of a sample of collected gas:—

Carbon dioxide	3·85 per cent.
Oxygen	13·46 ,,
Carbon monoxide	1·92 ,,
Nitrogen......................	80·77 ,,
	100·00 per cent.

The chemical changes in the gas are connected with the physical changes which take place during the ageing and weathering of clays. It is suggested that some study of the changes of chemical composition of the gases would throw light upon the question of the plasticity of the clay. A. M. J.

102. The Moulding of Clay Goods. (Brit. Pat. No. **111762**). B. J. Allen (February 15th, 1917, No. 2252).—Articles of clay, plumbago, silica, or the like are made by deposition from suspensions by electric endosmose on plaster or other porous moulds. The substance is mixed with liquid, with the addition of acid or alkali, and introduced into the mould. One metal electrode plate *B* is attached to the outside of the mould *A*, and the other electrode, *D*, is placed inside, the polarities being determined by the character of the substance. By reversing the current for a period or periods, or by varying the pressure, the porosity of the deposit may be increased. Deposits of varying thickness may be produced by placing plates of opposite polarities against different parts of the outside of the mould and operating as described in Specification 110649. Reversal of the current may also be employed for detaching the deposit from the mould. Superfluous liquid may be siphoned off and the residual moisture absorbed by the mould or extracted by a vacuum jacket, as described in Specification 110649. The apparatus shown is for making silica tubes. A suspension flows from a pipe, *I*, and vessel, *H*, through porcelain,

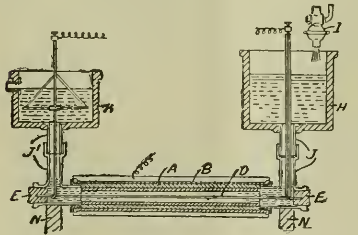


Fig. 8.

etc., tubes, *J*, to the mould, which is supported by insulators, *N*. Water escapes by pipes J^1 and a vessel *K*. Electric conductors pass through the vessels *H*, *K* to the interior electrode, *D*, which is held by non-conducting plugs, *E*. An apparatus for making Woulff's bottles, retorts, and stills has the absorbent mould enclosed in a vacuum chamber; the separated liquid is removed from the interior of the mould through perforated inner electrodes.

H. G. C.

103. The Moulding of Clay Goods. (Brit. Pat. No. **111775**). B. J. Allen (March 3rd, 1917, No. 3160).—Articles of clay, plumbago, silica, alumina, etc., are made by deposition from suspensions on metal moulds by electric endosmose. The suspension may be acid or alkaline, and may be poured into a type-metal mould (*a*) within which are hung one or more brass or other plates, or perforated tubes (*c*), forming the opposite electrode. Clear liquid may be siphoned off by tubes (*d*) from within the internal electrodes. These tubes may pass through charging funnels (*f*), being protected by insulation (*g*), and may be provided with terminals. The density of the deposit increases with the electric pressure. Reversal of the current facilitates removal of the completed article. The mould shown is for the production of Woulff's bottles. Crucibles, cores, tubes, muffles, basins, flasks, etc., also may be made.

H. G. C.

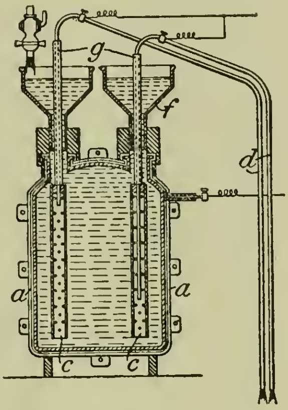


Fig. 9.

104. Heat Conductivity of Refractory Clays. H. A. Wheeler (*Trans. Amer. Cer. Soc.*, 1904, **6**, 119).—Experimental determinations were made of the heat conductivities of a number of clays. The method employed was to maintain one side of a slab of the clay at a constant high temperature, periodically noting the temperature of the other side. Data were thus obtained from which inferences could be drawn respecting the effect of various factors, namely, thickness, specific gravity, porosity, grog, and shape. The rate of heat conductivity varies inversely as the thickness. The effects of variation of specific gravity and porosity appeared to be small, and could not be estimated. The data indicated that an increase in the amount of grog decreases the heat conductivity, whilst a convex shape given to the test-piece increases the thermal gradient.

J. R. C.

105. The Action of Grog in Ceramic Bodies. S. Geijsbeek (*Trans. Amer. Cer. Soc.*, 1905, **7**, 133).—The shrinkage and porosities of a number of clays with varying percentages of grog were determined. It was found that the size of the grain of the grog had no effect on the shrinkage or porosity, provided the percentage of grog remained the same. An increase in the percentage of grog did not give rise to a proportional decrease in shrinkage nor a proportional increase in porosity. The first 10 per cent. addition of grog to a clay reduced the shrinkage and increased the porosity far in excess of any subsequent increase of the percentage of grog, and the effect of an increase of the percentage was less the higher this percentage.

In a discussion on the paper, many members stated that they found the shrinkage with fine grog to be a little more than with coarse. Others confirmed the author's statement. J. R. C.

106. Composition of Refractory Silica Bricks. J. S. McDowell (*Eng. and Min. J.*, 1918, **105**, 954).—A completely inverted brick should contain about 87 per cent. of tridymite and 13 per cent. of silicates. Apparently sixteen or seventeen burnings, or one continuous burning for a month, would be needed to reach this composition, so that the cost is prohibitive. So far as permanent expansion is concerned, there is little advantage in more than one burning, and, for practical purposes, none after the third burning. The author considers Wernicke and Wildschrey's statement that ordinary quartzites do not produce good silica bricks to be too sweeping, yet he confirms their general conclusion that the finer grained quartzites with a cement of amorphous silica are the most suitable for making bricks. He also confirms their statement that the selection of rock of the proper texture offers greater possibilities for the production of the best (*tridymite*) bricks than any alteration in the process of manufacture. A coarse texture brick spalls less than one composed of fine grains, but insufficient grinding may induce other defects. As there are often wide variations in the textures of quartzites of the same geological location, the averages of a sufficiently large number of grain-size measurements should be taken.

C. M. M.

107. Silica Refractories. D. W. Ross (*J. Amer. Cer. Soc.*, 1918, **1**, 477).—Silica bricks are made from quartzites of early geologic age, the most suitable ones ranging from the slightly porous to the highly metamorphosed, impervious rocks having tightly interlocking grains. If a thin section of a highly metamorphosed rock be viewed under the microscope, the interstitial impurities appear as sharply defined lines, whilst in slightly metamorphosed rocks the interstitial material appears as translucent, cloudy areas. Those quartzites which are crushed largely by a breaking through of the original grains are apt to yield silica brick of lower porosity than those in which the breaking is largely through the interstitial material between the built-up grains or those in which the original grains break free from the interstitial material.

Innovations in the methods of manufacture may be advisable in special cases in order to obtain greater uniformity of product. One such innovation is to control the grinding so that the percentages of the various sized particles in the mixture will remain constant at all times, and then to machine-mould the brick at a pressure of approximately 1,500 lb. per square inch in order to obtain a brick of smooth finish and of uniform size.

The porosity of a finished silica brick depends primarily upon the porosity of the unburned mixture. The heating of bricks which contain large percentages of unchanged quartz to temperatures above 1350° causes undue expansion, resulting in a more porous product. If, however, the temperature of the kiln be kept at 1250° to 1350° until a large percentage of the quartz has been transformed, and then slowly proceeding to higher temperatures, the bricks should have both a low porosity and a low specific gravity.

The specific gravity of a silica brick, as determined by the wet, dry, and suspended weight method, gives a means of judging the degree to which the original quartz has been transformed, but to obtain a comprehensive idea of the qualities of any silica brick, the chemical composition, porosity, cold cross-breaking strength, softening temperature, behaviour under load, and appearance in thin section under the microscope should also be determined.

A. M. J.

108. The Partial Purification of Zirconium Oxide. A. J. Phillips (*J. Amer. Cer. Soc.*, 1918, **1**, 791).—The problem investigated was to reduce the iron oxide content of crude zirconia to less than 0·1 per cent. without removing silica, alumina, and titanium oxide.

The crude material was ground to a fineness such that 75 per cent. passed a 100-mesh sieve.

Fusion with various fluxes, for example, Na_2SO_4, NaCl, NaF, fluorspar, and borax gave unsatisfactory results, as also did treatment with hydrochloric acid gas. The most successful results were obtained by mixing the zirconia with 4 per cent. of carbon, moulding the mass into small balls, and heating these in a current of chlorine gas in a vertical up-draught furnace.

The author concludes that an injection of low-pressure steam along with the chlorine would probably yield the most satisfactory results. It was found that the size of the balls was relatively unimportant, balls of $\frac{1}{4}$ inch and 1 inch diameter being chlorinated at the same rate and equally completely. The iron is volatilised as ferric chloride, the residue remaining in two samples treated being 0·04 per cent. and 0·03 per cent. respectively. The loss of zirconia through chlorination was about 5 per cent. in one case and 0·5 per cent. in the other.

J. H. D.

109. Production of Highly Refractory Ware from Non-argillaceous Materials, particularly Zirconia. H. Arnold (*Chem.-Zeit.*, 1918, **42**, 413, 426, 439).—Pure zirconia melts at about 2600°, has a coefficient of expansion of $8{\cdot}4 \times 10^{-7}$, is highly insensitive to sudden changes in temperature, readily dissolves other oxides, and has an electrical conductivity of 0·0008 at 1200°, which is increased to 0·00255 recip. ohm by adding 1 mol. of Al_2O_3 to 9 mols. of ZrO_2, to 0·0075 at 1000° if the alumina is replaced by CeO_2, and to 0·0358 at 1287° if replaced by Fe_2O_3. The author finds that the use of any fluid in pressing zirconia ware is detrimental, and recommends pressing the cold zirconia dry at 300 atm. on the hot material at 50 atm. A mixture of raw and highly calcined zirconia should be used, and as soon as the articles are dry they may be burned in an electric furnace at 2000—2300°, only about one hour being required for crucibles 2 in. high and $1\frac{1}{8}$ in. diam. The addition of a small percentage of alumina or clay is advantageous, but magnesia and silica make the ware too porous. Articles made of zirconia may be cast in plaster moulds, using a slip composed of graded zirconia and colloidal zirconia solution, the latter being prepared by repeatedly evaporating zirconium nitrate with twenty times its weight of water. The author measured the speed of translation of the particles of colloidal zirconia solution, and found that the speed is seriously affected by electrolytes in the zirconia. The plasticity of zirconia slip and the ease with which it leaves the mould are related to its electrical properties. The proportion of water in the slip must be regulated according to the rate at which it is to be absorbed by the mould. Non-porous moulds may be used if they have a low coefficient of expansion and are lined with wax or other readily fusible or soluble material, which may be removed before the article. Ware with walls only a fraction of a mm. thick may be cast in this manner. Zirconia ware should be supported on discs of carbon or zirconia and burned in an electric resistance furnace at 2000°; if burned at a higher temperature, its porosity is increased by the volatilisation of a further part of the impurities. Vessels of clay or other refractory materials may be lined or coated externally with zirconia, but such a method of protection has only a limited applicability. Hitherto, zirconia ware has not been glazed satisfactorily; a glaze composed of felspar 222·4, alumina 40·8, zirconia 147·6, magnesite 50·4, and quartz 69·6 parts burned on the ware at 1900—2000° is fairly satisfactory and does not craze, but is rather matt and liable to blister. There is a strong tendency for the zirconia to combine with glazes melting at a lower temperature, although when the product is sufficiently refractory they may be used. C. M. M.

110. Furnace Linings. (Brit. Pat. No. **111007**). I. Hall, Jan. 31st, 1917, No. 1558).—Crucible and like furnaces are lined and relined by means of a core, the bottom part of which is enlarged and adapted to form a combustion chamber. The core is placed in position in the furnace and packed round with refractory material. The larger part may be separated from the rest of the core and made in segments to facilitate withdrawal. The tangential inlet or inlets into the combustion chamber may be formed by separate cores inserted from the exterior to fit apertures in the main core, and they may also be made collapsible like the lower part of the main core. H. G. C.

111. Refractory Substances for Furnace Linings. (Brit. Pat. No. **111853**). H. A. Kennedy, *Pennsylvania, U.S.A., Clearfield*, (November 26th, 1917, No. 17454. Convention date, November 28th, 1916. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—A refractory material for furnace linings, etc., is made by clinkering, at a temperature higher than that employed in the manufacture of Portland cement, a finely divided and intimate mixture containing approximately 78—92 parts of CaO and MgO, 2—13 parts of SiO_2, and alumina or iron oxide, or both. To a certain extent, alumina and iron oxide may be replaced by silica or, in their place, basic slag, blast-furnace slag, bauxite, chrome iron ore, etc., may be employed. Magnesium limestone or dolomite is preferred as the source of CaO and MgO. The limestone may be first calcined and hydrated, and the materials may be mixed wet or dry. The heating is preferably effected in a rotary kiln by means of a powdered fuel flame, the kiln being inclined less or rotated more slowly than a cement kiln, so that the period of burning will be greater. The product is finally cooled in a cooling cylinder, and is then ready for use. H. G. C.

112. The Firing of Refractory Materials. (Brit. Pat. No. **111355**). A. Reynolds (December 4th, 1916, No. 17397).—In the manufacture of refractory bricks, etc., coherence is imparted to the article by subjecting the working surface or surfaces, after the usual burning, to a temperature sufficiently high to produce incipient fusion. Bricks are bedded in the floor of a furnace with the working surface uppermost, and the spaces between them are filled with a ramming of highly refractory material, such as chromite, plumbago, or ground carbon and tar, for example, fine coke and tar. For ladle nozzles, the articles are mounted in the end of a revolving furnace to prevent falling off of the incipiently fused portions. Fig. 10 shows a furnace (*a*) mounted on rollers (*b*) and lined with plumbago pieces, *f*, *g*, *h*, *i*, backed by spongy fire-brick (*e*) or other bad conductor. The nozzle (*k*) is mounted in the piece (*g*) on a fire-clay bedding (*l*). Stoppers for ladles are treated by mounting the article in a rod and revolving it within a horizontal passage in the fur-

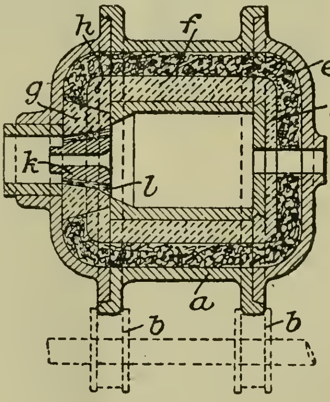


Fig. 10.

nace hearth, such passage being of slightly larger diameter than the article and communicating through slotted holes with the furnaces above and the atmosphere below, so that, as the article is revolved, its surface is subjected alternately to heating and cooling. Fig. 11 shows a suitable furnace lined with firebrick (*s*) in which there is a stoppered cavity containing a block (*t*) of plumbago, etc., provided with a slot (*u*), above which is a sliding cover (*v*) provided with a suitable burner opening (*w*). The stopper (*r*) is mounted on a refractory rod (*q*) in a cavity communicating with the atmosphere through lateral passages. H. G. C.

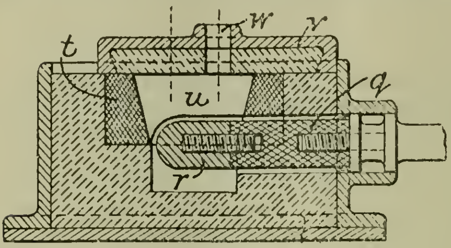


FIG. 11.

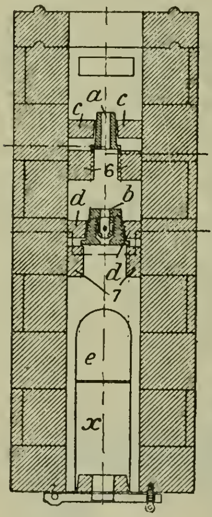


FIG. 12.

113. Nozzles for Coke Ovens.

(Brit. Pat. No. **111053**). D. BAGLEY, May 31st, 1917, No. 7800).—Comprises modifications in the nozzles which supply gas and air to the flues of coke ovens and like furnaces with vertical or horizontal series of flues. As shown in connection with a vertical-flued coke oven, gas is supplied through a tapering conduit (*e*) (Fig. 12) and passes to each heating flue through two nozzles, the lower of which (*b*) serves to regulate the quantity of gas supplied. H. G. C.

114. Heat Insulation and Lagging Materials.

J. S. F. GARD (*Chem. Trade J.*, 1919, **64**, 47).—Magnesia was found to be the most efficient lagging material for boilers, steam-pipes, and engines. In the form of "magnesia covering," which is the most suitable form, it is composed of hydrated magnesium carbonate, 85 per cent., and asbestos fibre, 15 per cent.; it has a density of 12—15 lb. per cub. ft., and will retain 85—87 per cent. of the heat which would escape from an uncovered pipe. Silicate cotton or slag wool is an efficient lagging material, but when subjected to vibration is reduced to half its original volume. Furnace settings are chiefly lagged with very light, porous silica bricks having a honeycomb structure and a density of 30—35 lb. per cub. ft. (compared with 112—125 lb. for common bricks and 137—150 lb. for firebricks). The graph representing the ratio of heat loss to thickness of covering of magnesia is almost hyperbolic, so that complete insulation is impossible. For a temperature of 400° F. (204·5° C.), covering more than 1½ in. thick is of little additional value. Above 400° F. a thickness of 2 in. is necessary. Where an acid-resisting lagging is required, magnesia covered with an acid-resisting coating was found to be best.

C. M. M.

115. Regenerative Coke Ovens. (Brit Pat. No. **111801**). D. Bagley (May 18th, 1917, No. 7138).—A regenerative oven with vertical heating flues has regenerators above and below each coking chamber extending along the length thereof, which operate alternately to heat the air supplied for combustion in the heating flues according to the direction of combustion therein, whether upwards or downwards. Gas is supplied to the heating flues (*v*) either from below or from above through conduits (*m*), being delivered through removable nozzles (Fig. 13). Air is admitted to the lower regenerator (s^1) through a conduit (*n*) with openings into the regenerator, which increase in diameter from the admission end of the conduit, and is supplied to the heating flues near the bottom thereof through channels in the walls having outlet ports at two levels. Similar air-supply conduits and channels are provided for the upper regenerator (*s*) for use when downward combustion is being effected. Suitable reversing valves are provided. With

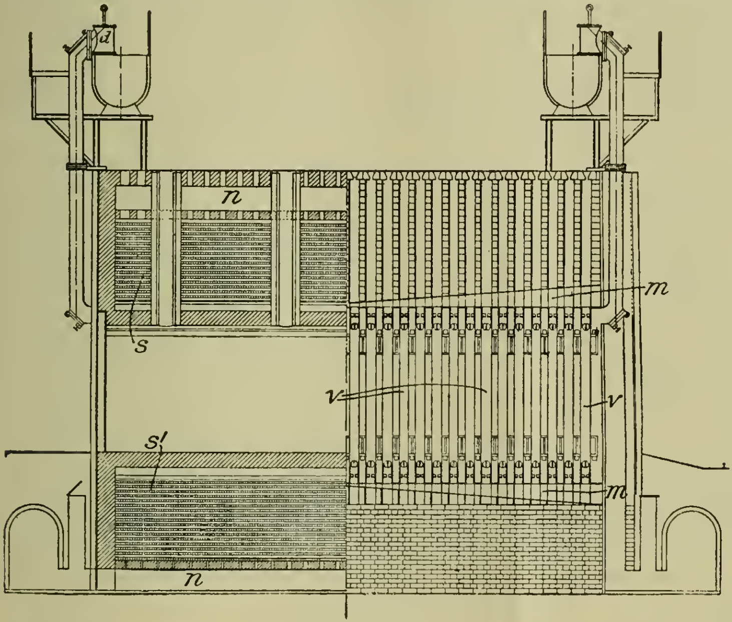


Fig. 13.

upward combustion, the waste gases pass into the upper regenerators, either through the channels which supply air for downward combustion, or directly from the tops of the heating flues, in the latter case entering the upper regenerators at the top and passing downwards therein. The air may pass to the upper regenerators through passages in the arches of the coking chambers.
H. G. C.

116. Heat Balance on a Producer-gas Fired Chamber Kiln. R. K. Hursh (*J. Amer. Cer. Soc.*, 1918, **1**, 567).—The data are based on tests made at the plant of the Baker Clay Company at Grand Ledge, Michigan, in the summer of 1917.

The equipment tested consisted of a kiln of sixteen chambers, each having a capacity of fifty to fifty-five thousand standard-sized bricks, and three 6-feet, water-sealed gas-producers of the pressure type.

Coal was weighed separately for each producer, and an average sample was reserved for analysis. Ashes were removed from the pits every other day, and a sample taken for analysis.

The steam pressure at the blowers of the producers was taken at hourly intervals, and the diameter of the orifice in the blower measured.

From the average pressure and the area of the orifice, the steam consumption was calculated by means of the Grashof formula. Samples of hot producer-gas were collected through a glass-lined sampling tube inserted in the gas main a short distance from the header. (No attempt was made to determine the soot and tar.) The temperature of the producer-gas was measured at the point of sampling by means of a base metal thermocouple. The temperature and humidity of the atmospheric air were determined by means of wet- and dry-bulb hygrometer readings. Temperatures in the tops of the kiln chambers were measured by means of a platinum platinum–rhodium thermocouple inserted through the crown holes. Flue-gas samples were taken from the main draught flue near the point of delivery from the kiln. The temperature was measured at the same point with a silver–constantan thermocouple.

The test covered the period of firing one chamber forty-four hours from the time the fires were started in it until its finish and the beginning of firing in the next chamber.

The following calculations were recorded:—

A. *For the Producer.*

(1) Volume of producer gas (4·73 cb. m. per 1 kg. of coal).

(2) Volume of dry air used (3·79 cb. m. at *N.T.P.* per kg. of coal).

(3) Moisture entering producer with the air (0·039 kg. per kg. of coal).

(4) Steam used in producers, calculated from the Grashof formula, $M=0{\cdot}0165Fp^{0{\cdot}97}$, where M=lb. steam flowing per sec., F=area of orifice in sq. in., p=absolute pressure of steam in lb.

per sq. in. (0·284 lb. of steam per lb. of coal, or kg. of steam per kg. of coal).

The moisture entering the producers from the moisture and combustion of hydrogen in the coal was 0·0258 + 0·039 × 9 = 0·377 kg. per kg. of coal. The total moisture entering the producers from all sources was therefore 0·039 + 0·284 + 0·377 = 0·700 kg. per kg. of coal fired.

(5) Free moisture in producer gas = difference between total moisture and the moisture equivalent of the free and combined hydrogen in the gas (0·263 kg. of free moisture in gas per kg. of coal fired).

(6) Calorific value of producer-gas from analysis (5095 Cals. per kg. of coal fired).

(7) Sensible heat of producer-gas. The average temperature of the producer-gas was 575°, and the average specific heats were obtained from the formulæ of Langen (991 Cals. per kg. of coal fired).

Total heat content of hot producer-gas = 5095 + 991 = 6086 Cals. per kg. of coal.

(8) Heat supplied to producers.

Heat content of dry air (av. temp. 17·5°) = 4·9 × 0·241 × 17·5 = 20·8 Cals. per kg. coal.

Heat content of moisture = 4·9 × 0·00801 × 604 = 23·7 Cals. per kg. of coal.

Heat content of steam (assuming it to be saturated at average pressure) = 0·284 × 644 = 183 Cals. per kg. of coal.

The calorific value of the coal was 7108.

∴ Total heat supplied to producers = 7108 + 23·7 + 20·8 + 183 = 7335 Cals. per kg. of coal.

∴ Hot gas efficiency = 6086/7335 = 82·97 per cent.

(9) The heat lost in unburned carbon in the ashes was 50 Cals. per kg. of coal.

(10) The heat losses due to conduction, radiation, etc., were determined by difference, and amounted to 1199 Cals. per kg. of coal.

This gives the heat balance of the gas-producers, which when tabulated is as follows:—

Heat in producer-gas calorific value plus sensible heat, 82·97 per cent.
Loss due to conduction, radiation, etc., 10·35 per cent.
Loss due to unburned carbon in ashes, 0·68 per cent.

B. *For the Kiln.*

(1) Volume of flue-gas and air used in kiln.
(2) Sensible heat of flue-gas.
(3) Heat used for burning the ware.

The heat value of the hot producer-gas, the heat in the atmospheric air supplied to the kiln, and the heat from the combustion of carbon in the clay constituted the heat input for the kiln. If this be 100 per cent., it was found that the heat required to raise the temperature of the clay and drive off water was 51·49 per cent. The losses due to sensible heat of flue-gas was 38·21 per cent., and losses due to conduction, radiation, etc., was 10·30 per cent.

Considering the kiln and producers as a unit, the total heat input from the coal used, air supplied to producers and kiln, and steam supplied to producers and carbon in the clay was 76,318,000 Cals. Of this amount, 43·59 per cent. went to the burning of the ware, 32·35 per cent. to the flue-gas, 8·72 per cent. to heat losses from the kiln, 14·72 per cent. to heat losses from the producers, and 0·62 per cent. loss was due to unburned carbon in the ashes.

A. M. J.

VIII.—Chemical Analysis.

117. Methods of Glass Analysis with Special Reference to Boric Oxide and the Two Oxides of Arsenic. E. T. Allen and E. G. Zies (*J. Amer. Cer. Soc.*, 1918, 1, 739).—After a critical study of the determination of arsenic in glass in trivalent and pentavalent form, the authors describe the following as the best method:—

(*a*) *Total Arsenic.*—Fuse up 1 gram of glass with 3 grams of Na_2CO_3 and 0·1 gram of KNO_3. Decompose the cake with 10 c.c. of 1:1 sulphuric acid (not hydrochloric acid, as this would volatilise some of the arsenic). Evaporate until white fumes appear, and continue the heating until the silica becomes dense. Cool the solution, add hot water, boil until any insoluble sulphates settle satisfactorily, and filter by suction. Add a small crystal of KI to the filtrate, heat, and precipitate the arsenic with H_2S in a flask. Stopper up the flask and allow to stand overnight. Filter off the As_2S_3, and wash with warm dilute H_2SO_4. Dissolve this precipitate with strong ammonia, and if any remains insoluble digest this with ammonia and ammonium carbonate, adding the soluble portion to the main arsenic solution. To this add about 5 c.c. of 3 per cent. hydrogen peroxide, and boil for some time on a hot plate until all the arsenic is oxidised and the excess of H_2O_2 decomposed. When the bulk is reduced to 10—15 c.c., acidify with about 7 c.c. of 1:1-sulphuric acid, and continue boiling for fifteen minutes. Transfer the solution to an Erlenmeyer flask, make up to 100 c.c. with hot water, add a small crystal of KI, insert a two-bulb trap in the neck of the flask, and boil until the free iodine has all been expelled and the bulk of the solution reduced to about 40 c.c. (It may be necessary to add more water and repeat the evaporation to 40 c.c. in order to drive off the whole of the iodine.) Dilute quickly with cold water to 75—100 c.c., and cool rapidly. Neutralise the bulk of the solution with a saturated solution of K_2CO_3, completing the neutralisation with solid sodium bicarbonate. Then add starch paste and titrate with a standard iodine solution containing 1·1 grams of I per litre.

In fourteen pairs of duplicate determinations the maximum variation was found to be 0·3 mg. and the mean variation 0·1 mg., using 1 gram of glass for each determination.

(*b*) *Separation of Tervalent and Pentavalent Arsenic.*—The sample is treated with HF and H_2SO_4 in a platinum crucible or small dish, the vessel being brought to a final maximum temperature of 200°. *All* the arsenious oxide is volatilised as trifluoride and *all* the arsenic oxide retained in the residue, in which it is determined by the Gooch and Browning method as above. The arsenic trioxide is determined by difference.

To verify the presence of tervalent arsenic, the authors distilled off the arsenic trifluoride as above, passed the gas into water, and determined the arsenic in solution. Positive results were obtained of the same order as the amounts found by difference.

Ferrous and ferric iron, and the small amounts of chloride usually found in glass, do not affect the determination.

Determination of Boric Oxide.—After testing the various methods used for the determination of boric acid, the authors conclude that Wherry's method, and its modification by Taylor and Sullivan, cannot be recommended for general use as a method of high accuracy, and state that their experience shows Chapin's method to be superior to all others, at any rate for the determination of boric oxide in glasses. The method is as follows:—

Fuse the powdered silicate with Na_2CO_3, take up the melt with 1:1-HCl, and volatilise the liberated boric acid as methyl borate by distillation with methyl alcohol in presence of granular $CaCl_2$. Treat the distillate with $N/2$- or $N/5$-NaOH (according to the amount of boric acid present), and distil off the methyl alcohol. Treat the alkaline borate with HCl and heat under proper conditions to expel CO_2. Finally, neutralise the excess of HCl with NaOH, using paranitrophenol as indicator, add mannite, and titrate the boric acid with standard NaOH, using phenolphthalein as indicator.

The authors confirm Chapin's statement that the method is trustworthy in presence of fluorides and oxides of zinc and arsenic (if in small quantity), and a blank determination indicated that no appreciable amount of boric acid was derived from the glass parts of the apparatus. (Probably this result would be different if fluorides were present.) A constant error was found to be due to traces of boric acid in the reagents used, and it is advisable to avoid excess of reagents as far as possible.

Commercial wood alcohol was not found to answer for the determination of boric acid. Impurities in the alcohol cause the sharpness of the end-point of the titrations to be obscured, and the results are only satisfactory when the methyl alcohol used is pure. If the substance contains large quantities of As_2O_3, the boric acid determination becomes inaccurate or impossible unless the As_2O_3 is first oxidised to As_2O_5 in an alkaline solution.

Determination of Iron in Optical Glasses.—The method advocated is as follows:—

The sample should be pulverised in agate, and not steel. Decompose 2 to 3 grams of the glass with 3 c.c. of 1:1-sulphuric acid and 5 c.c. of hydrofluoric acid, cool, transfer residue to a beaker with water, and boil well. Filter and wash. (This precipitate may contain as much as 50 per cent. of the total iron.) Remove the arsenic and lead by precipitation with H_2S. If zinc is present, neutralise the solution with Na_2CO_3, and add 0·3 to 0·5 excess of 50 per cent. formic acid before passing in H_2S. In a solution of this acidity, zinc sulphide is precipitated in a denser form than from alkaline solutions. The filtrate from the zinc sulphide is boiled to expel H_2S, and the iron precipitated by boiling with ammonia and hydrogen peroxide.

The insoluble sulphates are treated with hot ammoniacal ammonium acetate to remove lead sulphate, and the residue fused with potassium bisulphate. The iron is extracted by hot dilute H_2SO_4 and precipitated as above. The two iron precipitates are filtered and washed together, dissolved after fusion with bisulphate, and any trace of platinum in solution removed by H_2S, the excess gas being finally expelled from the solution by boiling in a current of pure CO_2. The cold solution is titrated with standard permanganate, which is best standardised by sodium oxalate. A careful blank test on the materials is essential.

Determination of Zinc.—After removal of lead and barium as sulphates, arsenic and zinc may be precipitated together in a formic acid solution. The zinc sulphide is dissolved out by hot 1:1-hydrochloric acid, and the zinc determined by (*a*) adding a slight excess of sulphuric acid, evaporating to dryness, and weighing as sulphate, (*b*) precipitating the zinc as carbonate and weighing as oxide, or (*c*) expelling the HCl by boiling with H_2SO_4, precipitating the zinc, and redissolving in excess of NaOH, acidifying the solution with acetic acid, and depositing the zinc electrolytically on a copper-coated platinum electrode.

Determination of Lead and Barium occurring together.—The authors state that they found it impossible to separate lead and barium sulphates satisfactorily with ammonium acetate, as some of the barium sulphate was invariably dissolved. They recommend determining lead and barium together as sulphates, and then determining the barium in a separate sample after removal of the lead, arsenic, iron, alumina, etc. It is pointed out that the barium sulphate always occludes some soluble sulphates, and the results are therefore slightly high.

If a direct determination of the lead is required, the glass is fused with sodium carbonate at the lowest possible temperature, the silica removed in the usual way, and the lead precipitated as sulphide, which is oxidised to sulphate by careful evaporation with nitric and sulphuric acids.

Separation of Aluminium from Barium and Calcium.—If an alkaline earth is present, the alumina precipitate with ammonia should always be reprecipitated. One of the authors prefers to precipitate the alumina by ammonium sulphide the first time, by making the filtrate from the zinc and arsenic slightly ammoniacal, and allowing the solution to stand overnight. In any case, *every filtrate* from the alumina should be evaporated to a small bulk and refiltered to arrest any alumina which may have passed again into solution.

Analysis of Borate Glasses.—After the solution has been evaporated for the second time to remove silica, cool the dish, add 25 c.c. of methyl alcohol, and evaporate to dryness. Repeat the evaporation with methyl alcohol to ensure the complete volatilisation of the boric acid as methyl borate.

In the determination of alkalis by Lawrence Smith's method, it is recommended that the mixed chlorides of alkalis and ammonium should be evaporated with 10 c.c. of methyl alcohol, keeping the dish covered.

Some data are given on the subject of gases in glass, an example showing 6·55 c.c. of gas obtained from 6·57 grams of powdered glass, the gas having the following percentage composition:—oxygen, 64·2; carbon dioxide, 24·2; carbon monoxide, 3·5; hydrogen, 3·9; nitrogen, 4·1. J. H. D.

118. A Study of the Sources of Error incident to the Lindo-Gladding Method for Determining Potash. T. E. Keitt and H. E. Shiver (*J. Ind. Eng. Chem.*, 1918, **10**, 994).—The authors' work proves that there are two sources of error in the Lindo-Gladding method for determining potash:—

(1) The volume of the solution is decreased by the bulk of the precipitate formed on addition of ammonia and ammonium oxalate, which makes a plus error.

(2) The potash in solution is decreased by occlusion of potash by the heavy gelatinous precipitate formed.

These two sources of error are partially compensating.

It is impossible to wash out with hot water the potash occluded within the precipitate, but it may be separated to a certain extent by repeatedly dissolving the precipitate in hydrochloric acid, diluting to a large volume, precipitating with ammonia and ammonium oxalate, filtering, and determining the potash in the filtrates and washings. The use of pure salts for making known strength solutions shows that both iron and calcium phosphate, when precipitated with ammonia, occlude potash, and that a combination of the two is even more effective in producing occlusion.

C. M. M.

119. Preventing Salts from Creeping. W. O. Robinson (*J. Amer. Chem. Soc.*, 1918, **40**, 197).—The author states that if the inner rim of an evaporating dish be painted with a strip of collodion about $\frac{1}{4}$ inch wide, creeping is entirely prevented, and the collodion has the advantage that it dries immediately and leaves no residue on ignition. J. D. C.

120. Solubility of Silica. V. LENHER and H. B. MERRILL (*J. Amer. Chem. Soc.*, 1917, **39**, 2630).—Silica, even in the form of quartz, is somewhat soluble in water and dilute acids, and various workers have recorded that a quantitative estimation of silica is in error, due to the solvent action of dilute hydrochloric acid.

The authors have carried out determinations of the solubility of silica in various solvents. By their procedure, what was measured was the amount of silica which changed from an unfilterable to a filterable state. The solvents used were hydrochloric acid of various strengths, sulphuric acid, conductivity water, and water saturated with carbon dioxide. Most of the experiments were made with gelatinous silica, but other forms were also tested. The solubility of silica was found to be definite and to depend both on the temperature and the concentration. With gelatinous silica, equilibrium was reached in a few hours, or at most days, but with ignited silica, saturation was not reached in days or weeks. The solubility of gelatinous silica was the same, no matter how prepared. The true solubility of ignited silica is probably the same as that of gelatinous, but this could not be tested in any reasonable length of time.

The paper contains numerous tables and graphs of results.

J. D. C.

121. Determination of Moisture in Coke. A. C. FIELDNER and W. A. SELVIG (*Chem. News*, 1918, **117**, 172).—Owing to the more stable character of coke as compared with coal, much simpler methods may be employed for the estimation of moisture in the former, and, in fact, it may be sampled and tested very much in the same way as iron ores. It was found that the influence of temperature, humidity of drying atmosphere, and fineness of sample are of comparatively small importance, and these factors may be varied over a considerable range. Coke can be dried to constant weight in an oven without undergoing any increase in weight during heating, and oven temperatures ranging from 105° to 200° produced a maximum variation in the moisture results of 0·3 per cent. The effect of the fineness of the sample was tested by making moisture determinations as:—(*a*) sample crushed to pass 60-mesh sieve and dried at 105°, (*b*) sample crushed to pass 4-mesh sieve and dried at 105—150°, and (*c*) lump coke placed on a galvanised iron tray to a depth of 2 inches and heated on a hot plate to 100—200°. Practically the same result was obtained in each case, thus showing that moisture determinations on small lump coke are sufficiently accurate for practical purposes, thus obviating the necessity for grinding, etc.

The only sources of error to be feared are those connected with the taking and preparation of the sample. The authors discuss a suitable procedure for this. J. D. C.

122. Valuation of Lime for Various Purposes. R. K. MEADE (*J. Ind. Eng. Chem.*, 1918, **10**, 214).—Lime may be valued according to its chemical composition or its physical properties.

For building purposes and plastering, the physical properties are of highest importance, and the author discusses suitable tests for these. As regards chemical composition, the sum of calcium and magnesium oxides should amount to 90 per cent. for selected and 85 per cent. for average quicklimes. Quicklime for most chemical purposes is valued on the sum of the free calcium and magnesium oxides, although in some industries the presence of magnesia is objectionable. The methods for the titration of the free calcium oxide or hydroxide were discussed. Water free from carbon dioxide is recommended for use. Twenty-eight grams of the lime are boiled with water for ten minutes, and then diluted to 1 litre and agitated. Fifty c.c. of the well-agitated milk are drawn off and titrated, using phenolphthalein as indicator. In a modification of this method, a preliminary titration is made with $N/1$-hydrochloric acid on a milk prepared by boiling 1·4 grams of the finely ground material with 80 c.c. of water. The test is then repeated, using 5 c.c. less acid than was found in the preliminary test. Any small lumps are ground up with the round end of a thick glass rod, the pink mixture is transferred to a 250 c.c. graduated flask, diluted to the mark, and allowed to settle for half an hour. One hundred c.c. are then withdrawn and titrated slowly with $N/1$-hydrochloric acid, using phenolphthalein as indicator.

Other methods described are: Lunge's oxalic acid titration method; Spencer's cane-sugar method, using a cane-sugar solution of 35 to 45 per cent. strength to dissolve the calcium hydroxide; Solvay's method, in which a solution of ammonium chloride is employed, this method being very trustworthy, but requiring a reaction flask of special design; and another method, which is sometimes used in caustic soda manufacture, in which the value of the lime is determined by causticising sodium carbonate and precipitating the excess of the latter with barium chloride before titration. J. D. C.

123. Estimation of Lead as Phosphate and its Separation from Antimony. G. Vortmann and A. Bader (*Zeitsch. anal. Chem.*, 1917, **56**, 577).—The following method is stated to give trustworthy results for lead and a good separation of lead from antimony.

A solution containing 0·3 gram of lead is treated with 5 grams of tartaric acid, then made slightly ammoniacal, heated to 80°, and 100 c.c. of 10 per cent. ammonium phosphate solution are then added. The mixture is kept at 70° to 80° for sixteen hours, then cooled, the precipitate filtered off, washed with dilute ammonium nitrate solution, dried, ignited at a low temperature, and weighed. The amount of tartaric acid should be increased if much antimony is present. The antimony can be precipitated as sulphide from the filtrate from the lead phosphate precipitate.

J. D. C.

IX.—Machinery for the Working of Glass.

124. Automatic Glass Bottle Machines. (Brit. Pat. No. **111868**). A. Wilzin (October 11th, 1916, No. 14445).—Relates to glass shaping and blowing machines of the kind in which, after the introduction of the glass into the parison mould, the several and subsequent operations on the parison and on the finished bottle are performed automatically and in proper sequence, the duration of the several operations being capable of variation at will and independently, as described in Specifications 7183/12, 20299/13, and 3146/15, and comprises automatically controlled means for (1) submitting the parison to an automatically controlled temperature equalisation process, the duration of which may be varied at will by means of a controlling device with adjustable dogs, etc., which connect with or disconnect the machine from the source of power, (2) forcing the glass into intimate contact with the walls of the parison mould, and (3) expediting the stretching of the parison. The operator delivers a quantity of glass from his gathering-rod into the parison mould 55, the penetration of the glass to the neck mould 75 being ensured by the connection of the mould to a source of negative pressure air passing through a pipe 135, and through a passage adjacent to the indenting plunger 76. By then pressing a pedal, a clutch is coupled up and a loose control wheel 24 is caused to make one revolution. The control wheel 24 carries a series of depressions, pins, and adjustable dogs, which control the times and sequence of the various operations of the machine. The first movement of the control wheel 24 cuts off the air and allows a pair of spring-actuated shearing blades, 99, 100, to sever the glass hanging from the gathering-rod. The continued rotation of the control wheel 24 intermittently operates a clutch so as to produce intermittent rotational movements in a pair of cam discs, 4, 5, secured to shaft 3. The first movement of the cam discs, by operating a rack 60 gearing with a pinion 59, rotates the parison mould 55 through 180 degrees, the plunger 76 being withdrawn from the neck mould by a cam groove 79 on the frame, and the lower end of the parison mould being closed by a bottom mould. An adjustable dog on the periphery of the control wheel 24 opens a valve and allows high-pressure air to pass through the pipe 135 and act on the cavity formed by the plunger 76, thus pressing the whole surface of the parison into intimate contact with the walls of the parison mould and minimising temperature variations due to local contacts.

The air is cut off and the cam discs 4, 5, again rotate, thus causing the hinged halves of the parison mould to swing open and leave the parison supported by the neck and bottom moulds only. Whilst in this condition, the inner heat of the parison restores the surface to a more uniform temperature, the duration of this pause, as also the other steps in the process, being regulated by the adjustable dogs on the control wheel 24. A further movement of the cam discs 4, 5 removes the bottom of the parison mould and brings the bottom mould 103 of the finishing mould into position, and the stretching of the parison commences, such stretching being assisted, if desired, by the admission of puffs of low-pressure air liberated by means of pins projecting from the control wheel. A still further movement of the cam discs 4, 5 closes the finishing mould about the parison, and the blowing is completed by re-admitting the high-pressure air. On completing a whole rotation, the cam discs 4, 5 restore the various parts to their initial positions, and, by opening the finishing and neck moulds, drop the blown bottle into a divided cooling pot 117, whence, after the bottom of the bottle has been indented by a reciprocating spigot 123*a*, the bottle is tipped down a shoot. The hinged halves of the neck mould are held in closed position by a spring, and are opened to drop the bottle by the opening movement of the finishing mould. When dealing with bottles having internal screw-threads at the mouth, the plunger 76 is provided with a screw-thread of corre-

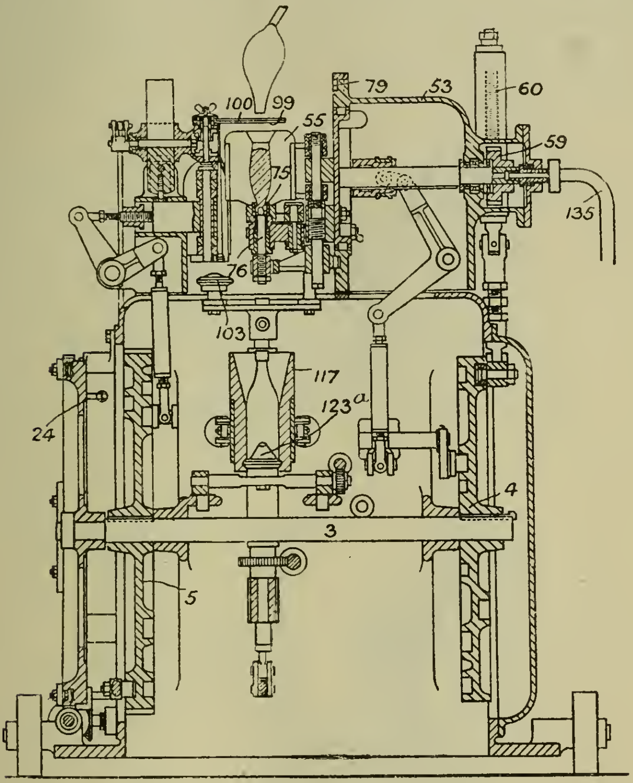


FIG. 14.

sponding pitch, and during its withdrawal is given a rotary movement by means of a gear connection, which is substituted for the cam 79. H. G. C.

125. Automatic Glass Gathering. (Brit. Pat. No. **111701**). A. Wilzin (December 4th, 1916, No. 17382).—Relates to a modification of the automatic glass-gathering device, shown in Fig. 16 of Specification 3146/15, wherein the molten glass is sucked into the parison mould 9 (Fig. 15) through a tube 4. According to the present invention, after removal of the parison mould, the tube is raised clear of the molten glass, thus allowing the furnace flames to pass through and around the tube, as shown in Fig. 16. The tube is arranged within a pocket 2 projecting into the furnace, and is carried by internal projections on a collar 5 mounted on the end of a lever 6. The bore of the gathering tube is greater than that of the inlet to the parison mould, so that the rising glass forms an airtight joint between the two. The pocket 2 may be provided with a tube 7 to direct flame on the top of the gathering tube, a shield 8 being interposed when the parison mould comes into the gathering position. H. G. C.

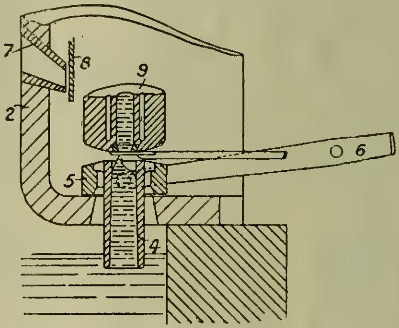


Fig. 15.

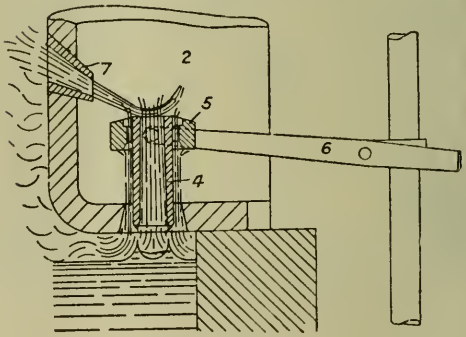


Fig. 16.

126. Glass-making Machinery. (Brit. Pat. No. **112007**). E. Roirant (September 14th, 1917, No. 13190. Convention date, December 14th, 1916. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—The parison and finishing moulds of a glass-blowing machine are hinged on separate and fixed axes and have opening and closing movements only, and the opening or closing movement of the parison mould and the closing or opening movement of the finishing mould commence and finish at the same time. The halves 21 of the parison-mould carrier are hinged to one of the hollow columns 2 of the machine, and the halves 22 of the finishing-mould carrier are hinged to the other column. The moulds are mounted at the same level, and are coupled by adjustable members 23, 24 to the lower ends of pivoted levers 16, 17, which are operated by rods 18, 20 from an eccentric pin 19 on a disc 9 on the driving shaft 4. The carrier 13 of the bottom mould 14 is moved up and down on the columns 2 by a rod 15 connected to a sprocket wheel 10, which is contained within the hollow base 1 of the machine and driven by a chain 12 passing through the columns 2 from a wheel 7 on the shaft 4. The bipartite neck mould 25 is carried by slides 26 mounted in a carrier 27 loosely seated on the lower part of the casting 3. Cams 34 on discs 6, 9 on the shaft 4 engage rollers 32 on the upper ends of levers 30, 31

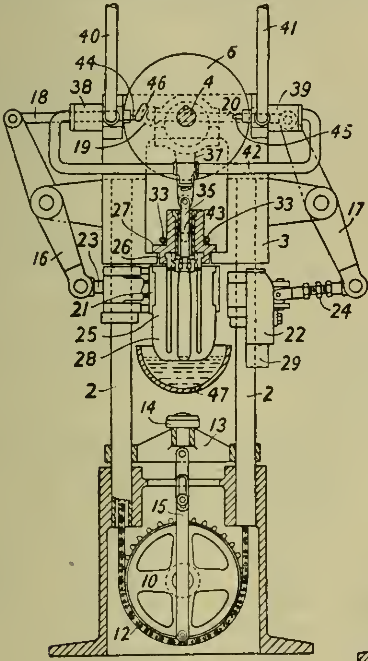


Fig. 17.

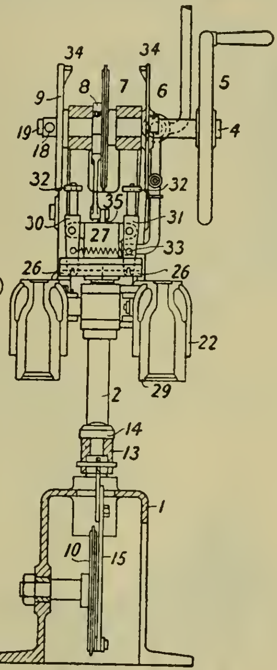


Fig. 18.

pivoted to the carrier 27, and move the parts of the neck mould 25 apart against the action of springs 33. An eccentric 8 on the shaft 4 actuates the plunger 35. The carrier 27 is connected by pipes 43, 42 to chests 38, 39, which communicate by pipes 40, 41 with sources of vacuum and compressed air respectively, and the valves in the chests are opened sequentially by a cam 46 on the disc 6 to drain molten metal from the receptacle 47 into the parison mould 28 and to blow the parison in the finishing mould 29. H. G. C.

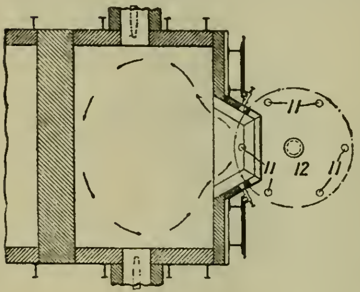


Fig. 19.

127. Automatic Gathering of Glass by Suction. (Brit. Pat. No. **111890**). C. F. Cox (December 11th, 1916, No. 17791).—In a method of gathering glass from a furnace, the suction moulds 11, carried on a rotating table 12, dip into the glass, and during their passage through it create a circulation, as indicated by arrows, thus replacing chilled glass by hotter glass at the gathering place. Instead of creating the circulation by means of the moulds, a series of drags actuated by or independent of the gathering machine may be drawn through the glass. Specification 2992/07 is referred to. H. G. C.

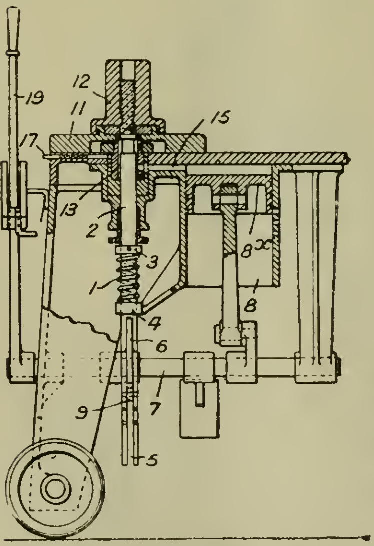


Fig. 20.

128. Semi-automatic Bottle-making Machine. (Brit. Pat. No. **111231**). A. E. Clegg (April 10th, 1917, No. 4983). —In machines for blowing glass bottles and of the type in which the molten glass is drawn into the ring mould of the preliminary mould 12 by suction produced by means of a hand-operated piston 8*x* working in a stationary cylinder 8, and in which the blowing in the preliminary and finishing moulds is effected by compressed air supplied thereto from a source independent of the suction cylinder 8, the piercing plunger 2 is normally held in the piercing position by a spring 1, and is retired during the concluding portion of the suction stroke of the piston 8*x* by means of a lever 6 fixed on the shaft 7 of the hand lever 19 which operates the piston 8x. The spiral spring 1 is mounted on the plunger between a collar 3 and a stationary guide bracket 4, and the lever 6 works in a slot 5 in the lower portion of the plunger and engages an adjustable stop 9 thereon. A rotatable ring-like plug 13, formed with ports to communicate with the suction and compressed-air channels 15, 17, is mounted around the plunger immediately beneath the carrier 11 of the mould 12. The plug 13 is operated by means of a hand lever, the movement being limited by stops. H. G. C.

129. Automatic Electric Bulb-making Machine. (111258). Westlake European Machine Co., Spitzer Building, *Toledo, Ohio, U.S.A.* (Assignees of A. Ladou, Spitzer Building, Toledo, Ohio, U.S.A. June 18th, 1917, No. 8757. Convention date, December 28th, 1916. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—In a machine for making electric lamp bulbs, etc., and of the type described in Specification 26222/11, in which sets of glass-forming apparatus are carried by an horizontally rotating support, and the blowing spindles, after receiving the gathers, are turned over to complete the blowing, the blank hanging downwardly from the spindle is elongated by imparting to it a series of reciprocating movements in the direction of its length. Each hollow blowing spindle 11 receives a solid blank from the gathering-ram while in the vertical position with the blank-holding means 12 upwards. The blank is blown into hollow form while the spindle is rotated through pinions 28, 27 and bevel wheels 25, 24 from a shaft 21 rotated through a worm gear and rack from a stationary cam as the support rotates. The spindle is then inverted to the position shown by a gear wheel 34 meshing with a gear wheel 35 keyed to a sleeve 36 forming part of the spindle support 23, the wheel 34 being rotated through a spiral pinion and a rack actuated

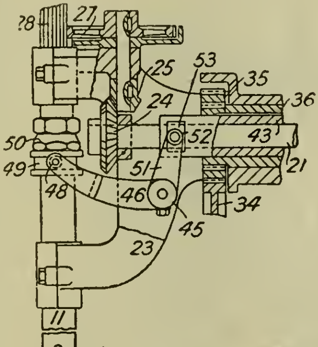


Fig. 21.

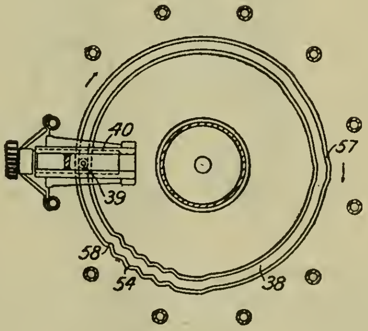


Fig. 22.

by a stationary cam. The spindle is then reciprocated longitudinally to elongate the blank 55 by a bell-crank lever 45 having a forked arm 46 with rollers 48 engaging a grooved collar 49 on the spindle and adapted to bear against a stop-nut 50. The other arm 51 of the bell-crank lever 45 is in the form of a fork having rollers 52 engaging recesses 53 in a sleeve 43, which is reciprocated on the shaft 21 by a slide 40 (Fig. 22) provided with a roller 39 engaging a stationary cam-way 38 having a series of bends 54 for this purpose. Bends 57, 58 on the cam-way 38 act respectively to raise the spindle 11 when it receives the blank from the gathering-iron, and to lower it when it is enclosed by the finishing mould. The reciprocation of the spindle may be accompanied by the controlled admission of compressed air. H. G. C.

130. Automatic Machines for Electric Bulb-making. (Brit. Pat. No. **111122**.) A. E. White (Westlake European Machine Co.; *Ohio, U.S.A.*, September 12th, 1916, No. 12895).—

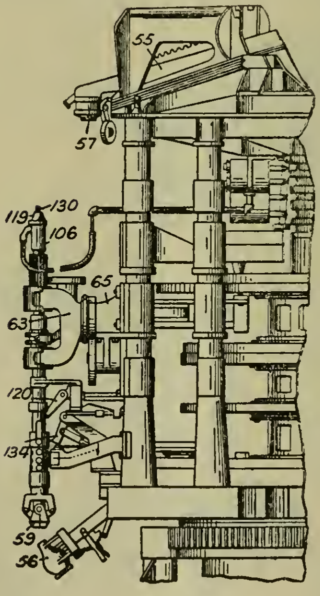


Fig. 23.

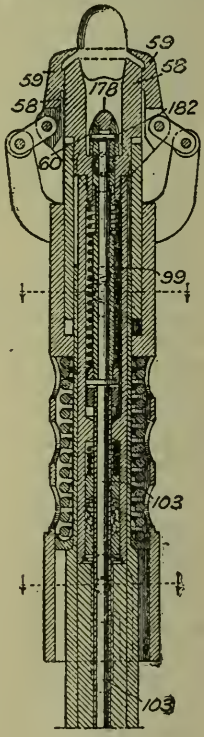


Fig. 24.

Relates to the type of automatic glass-blowing machine for making electric lamp bulbs, etc., described in Specifications 26222/11 and 26224/11, wherein a series of gathering mechanisms 55 (Fig. 23) carried on a rotating frame successively suck up metal from a furnace into blank moulds 57 and transfer the blanks thus formed to their respective blowing spindles, the cycle of operations of each set of moulds and co-operating parts being the same. The blank-piercing plunger 60 (Fig. 24) is constructed with a tip 178 of graphite or copper, separated from the body portion to prevent over-cooling of the glass. The operating rod 99, 103 of the plunger is made in two separate sections arranged in alignment similar to the sectional plunger described in Specification 26224/11, and the sections are spring-pressed to obtain an instantaneous action of the plunger. The longitudinal air passage in the plunger communicates with a transverse duct 182 leading into grooves on the exterior of the plunger. The blowing spindle is slidably mounted in a yoke 63, which is rotatable in a casting 65 secured to the rotating frame of the machine. When the blank is received by the blowing spindle from the blank mould, the blank holder 58 is in its lower position and the pivoted jaws 59 are open, the spindle then having the opposite end up from that shown in Fig. 23. A fork 120 is then rocked away from engagement with a projection 119 on a casing 106, thus allowing springs within the blowing spindle to close the jaws 59 and to raise the blank holder 58 so as to grip the blank. The plunger 60 is caused by the action of an arm 134 on a tip 130 to indent the blank. The blowing spindle is subsequently turned almost to a horizontal position, and is caused to rotate about its longitudinal axis, preferably with the admission of air to the blank, the inversion of the spindle to the position shown in Fig. 24 being afterwards completed. The spindle is afterwards oscillated by a worm gearing and under the control of a brake with the blank hanging downwards, and the bulb is finished in the mould 56. H. G. C.

131. Automatic Electric Bulb Machine. (Brit. Pat. No. **112221**). A. E. White (Westlake European Machine Co., *Ohio, U.S.A.*, September 12th, 1916, No. 5580/17).—Relates to glass-blowing machines of the type described in Specification 26222/11 for making electric lamp bulbs, etc., and consists in providing means for varying, during the operation of the machine, the intensity of the vacuum produced in the gathering mould while the blank is held therein and before it is delivered to the spindle. Means are provided for adjusting the opening of the suction valve and for varying the moment of activation of the actuating cam without interrupting the operation of the machine. The spring-pressed valve 717 (Fig. 25), which puts the gathering or blank mould in communication with the exhausting apparatus, is operated by a member 731 (Fig. 26) carried by an element 728 which is mounted on a bracket 730 carried by the rotating spider 50, and rocked on its pivot 729 by a cam 711 on the stationary drum 54 engaging a roller 745 on arm 746. The pin 731 is adjustable by means of worm gearing 733, 735 operated by a hand-shaft 736 to vary the distance between the end of the valve stem 718 and the head 732 of the pin 731. The arm 746 and roller 745 are adjustable laterally by means of a screw 756, a dovetailed projection 747 at the upper end of the arm engaging a groove in a block 751 forming the lower part of the rocking member 728. The end part 711*a* (Fig. 27) of the cam 711 is reduced so that, when the roller 745 rides on this part, the value 717 is held only slightly open to diminish the vacuum at the back of the blank. Specification 111122 also is referred to. H. G. C.

FIG. 25.

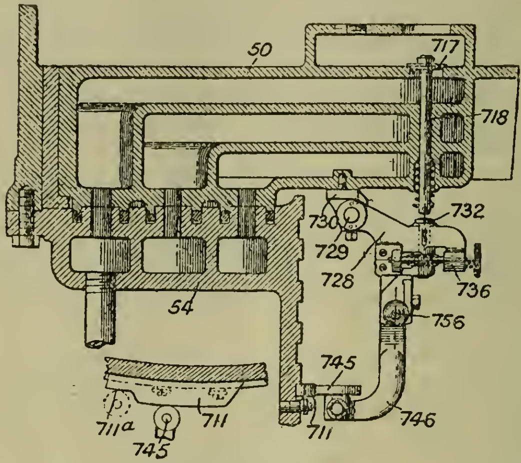


FIG. 27.

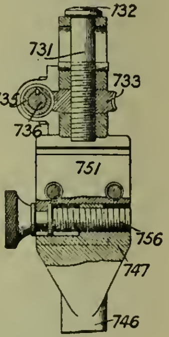


FIG. 26.

132. Automatic Machinery for Electric Bulb-making. Brit. Pat. No. **112613**). WESTLAKE EUROPEAN MACHINE Co. (Assignees of A. KADOW, Spitzer Building, Toledo, Ohio, U.S.A. June 18th, 1917, No. 8758. Convention date, January 11th. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—Relates to gathering apparatus of the kind described in Specification 26222/11, in which one or more gathering rams or devices are carried on a rotating structure and periodically brought opposite to and thrust into the working opening of a stationary glass furnace with a closed top, and consists in making the gather by a radial movement of the ram without interrupting the continuous rotary movement of the ram and without arresting the rotary move-

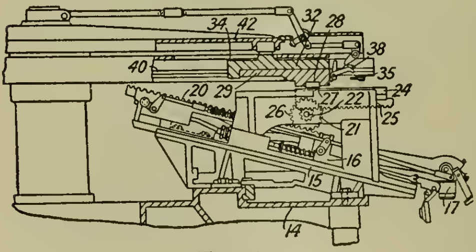


FIG. 28.

ment of the supporting structure. The ram 16 carrying the gathering moulds 17 slides on an inclined support 15 on a plate 14 carried by the rotary structure, and a slide 24 in the upper part of the housing 15 has a rack 25 gearing with a pinion 26 on a shaft 22 carrying a pinion 21 gearing with a rack 20 on the ram 16. As the structure rotates, a roller 27 on the slide 24 enters a curved slot 28 in a slide 29 on a stationary structure opposite the opening of the furnace. The slide 29 is engaged with a slide 32, and the two slides are moved in guides 40 by a rotating cam 42. The slides 29, 32 are held together by a shoulder 34 on the upper slide 32 and by a spring-pressed dog 35 pivoted in the lower slide and engaging a notch 38 in the upper slide. By disengaging the dog 35, the ram 16 may be disconnected from its actuating mechanism.

H. G. C.

133. Machine for Drawing Glass Tubing. (Brit. Pat. No. **111521**). E. C. R. Marks (*Libbey Glass Co., Ash Street, Toledo, Ohio, U.S.A.*, November 29th, 1916, No. 17132).—Relates to apparatus for drawing glass lengthways. The molten glass is

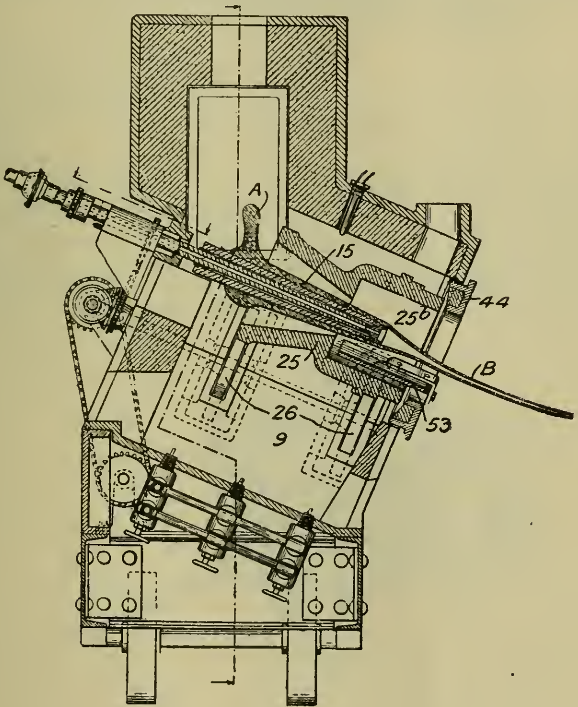


Fig. 29.

placed in a trough 3 (Fig. 30) above a furnace 2, and, after flowing down a step to eliminate air bubbles, passes beneath an adjustable gate 11, and flows in a stream *A* on to the exterior of a hollow rotating mandrel 15 (Fig. 29) situated in an independently heated furnace chamber 9. The mandrel, which may be adjusted longitudinally while in action, projects into a casing 25, which is continuously rotated on wheels 26 so as to radiate heat uniformly to the glass on the mandrel. The casing is enlarged at the exit portion 25*b*, thereby allowing a slight cooling of the glass before leaving the mandrel. A ring-like door 44 carrying a trough 53 to catch falling particles from the mandrel closes the furnace opening around the casing 25. In operation, the stream *A* of glass winds around and flows down the rotating mandrel, and is drawn off in the form of a tube *B* by means of any suitable drawing device, air under slight pressure or at atmospheric pressure being continuously supplied through a mandrel. In drawing a solid rod, the end of the mandrel is closed by an imperforate tip. In a modification, Fig. 31, the mandrel is surrounded by a conical casing 43, which is partially filled with molten glass, the thickness of the glass film being regulated by the size of the outlet. In a further modification, the rotating shell enclosing the mandrel is replaced by a stationary housing 68 (Fig. 32), and the molten glass in the furnace trough is shielded from direct contact with the flames. The mandrel is rotatably mounted in a bearing 72 carried by an arm, which may be adjusted so as to vary the inclination of the mandrel without varying the height of the stream *A* of glass. The wide end of the housing 68 is closed by a vertically sliding door 81

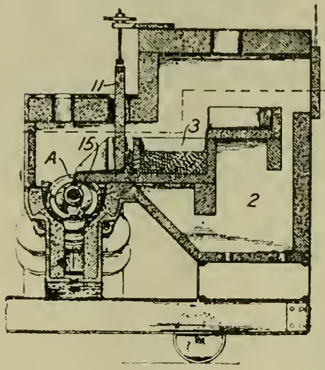


FIG. 30.

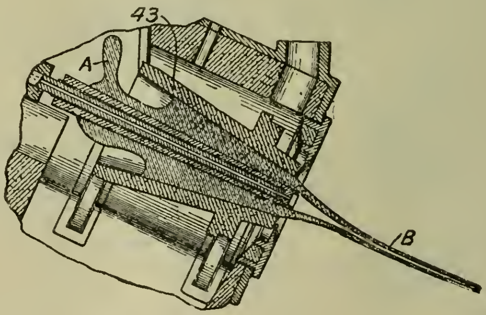


FIG. 31.

with the exception of a slot 82 for the passage of the drawn glass, and the slot is restricted by a pair of suspended plates 87, these

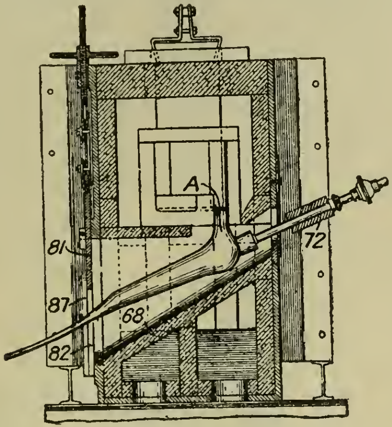


Fig. 32.

closures affording means for regulating the temperature of the housing 68. H. G. C.

134. Grinding and Polishing Machinery. (Brit. Pat. No. **111715**). W. Taylor (December 7th, 1916, No. 17600).—In a machine for grinding spherical surfaces, and especially the convex surfaces of lenses made from discs of glass, of the type in which the work rotates about a primary axis and the work or grinding disc is also given a movement relatively to the grinding wheel about a secondary axis at right angles to the primary axis, the movement about the secondary axis is produced automatically and in such a manner that the grinding is effected at one side only of the axis of the work and during a single movement of the work about the secondary carried by an adjustable slide, *B*. The spindle, *F*, is carried in bearings in a slide, F_5, provided with micrometer adjusting means, and is driven through worm gear, F_7, F_8, by a band passing round a pulley, F_{10}. The band also passes around guide pulleys, *L*, L_1, carried by a bracket on a double-hinged arm, L_2, which is also connected to the worm shaft, F_9, by a strut, L_3, to maintain the tension in the band. The slide F_5 is supported on a carriage, *H*, adapted to be turned about the secondary axis, *I*. The grinding is done from the periphery to the centre of the work, and the rate of movement of the work may vary inversely with the resistance to grinding, but cannot exceed a definite rate. The movement about the axis *I* is controlled by a weight, N_3 (Fig. 34), which in falling carries with it a nut, N_2, working on a screw, *N*, the axis of which is coincident with the secondary axis, *I*. The weight is prevented from turning by a pin fixed in the column *O* and engaging in a groove in the weight. The nut N_2 is locked to the weight as it falls, and causes the screw N to rotate. The weight is lifted to the requisite height by a treadle, O_1, and cranks, O_3, O_4, on a stud shaft, O_2. The speed with which the weight falls is controlled to accelerate or decelerate the movement of the work by means comprising a dash-pot, R, the crank arm R_1 of axis; further, the work and grinding disc are separated automatically when the grinding is complete. The work is mounted by spring means on a spindle, F, and is ground by the face of a cup-shaped wheel, A, which is connected by a link, R_2, with a crank arm, R_3, on the spindle, N. Further, the cranks O_3, O_4 may be

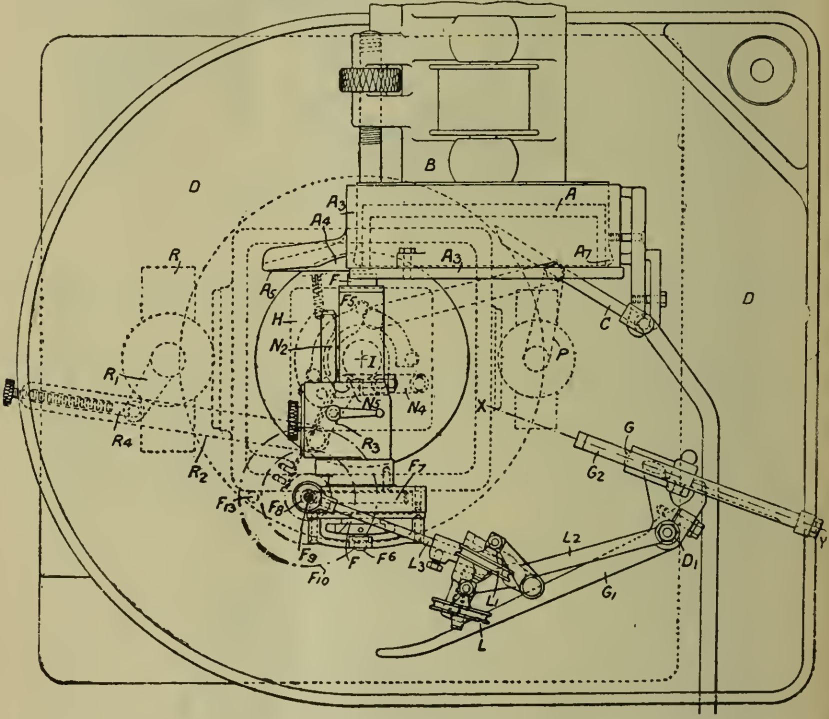


FIG. 33.

set so that the effective weight of the treadle, O_1, varies during the grinding operation. Additional weights, N_{10}, N_{11}, may be added. When the grinding operation is finished, the toggle arms, N_4, N_5, which form the means whereby the nut, N_2, and weight, N_3, are locked together, are bent by a suitable projection to allow the nut to rotate within the weight, and a spring arm, P, to rotate the carriage H about the axis I to bring the axis of the work spindle into a position of rest, XY, where a handle (G_1) may be operated to press forward a thrust rod (G) and release the work by pressing the abutment, F_6, against the action of a spring. The pillar, D, which supports the parts G, G_1, also carries a stop, G_2, which is engaged by a projection, F_{13}, on the pulley, F_{10}, and prevents further rotation of the work spindle. When a fresh blank has been inserted, the weight, N_3, is raised by a treadle, O_1, and the weight and nut, N_2, are locked together. The weight on commencing to fall turns the carriage H rapidly about the axis I into the working position. This movement is accomplished without opposition from the dash-pot R, which only comes into operation during the actual grinding. To allow this, the link, R_2, is provided with a slot, R_4, in which the end of the arm, R_1, engages.

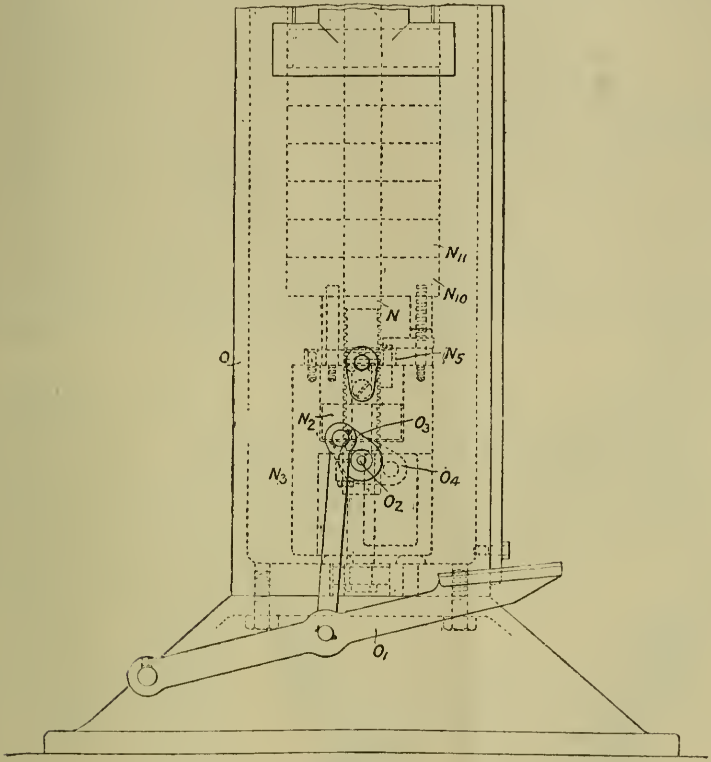


FIG. 34.

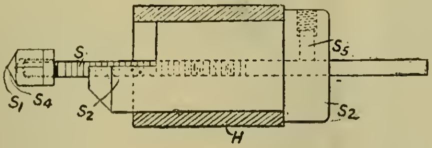


FIG. 35.

The position of the work may be fixed, and movement about the secondary axis be imparted to the grinding wheel. To grind concave surfaces, the work is withdrawn to the other side of the secondary axis, and is ground by the periphery of a disc. To ensure uniform thickness of the finished work, the work spindle, F, has limited end play in its bearing, and the end thrust is taken by an abutment, F_6. To allow of accurate setting, a bar, S (Fig. 35), is mounted in the carriage, H, in a position parallel to the work spindle. The bar is graduated, and is clamped in the correct position in a slider, S_2, by a screw, S_5. The slider is set to abut against a fixed surface on the carriage, H, and the bar has an adjustable end, S_1, with a diamond, S_4, adapted to touch the grinding disc. The wheel A is provided with a guard, A_3, adjustable longitudinally along the axis of the wheel. The guard has an opening, A_4, at one side to permit the work to be applied to the wheel, and an opening at the bottom to permit the escape of the liquid supplied through the pipe C. The opening, A_4, is screened by a curved part, A_5, designed to prevent splashing of the liquid projected against it, and the interior of the guard has a groove, A_7, curved to prevent atomisation of the water projected against it.

Specification 15375/15 is referred to in the Provisional Specification.
H. G. C.

135. Grinding and Polishing Lenses. (Brit. Pat. No. **112297.**) H. O. Gowlland (December 30th, 1916, No. 18681). —Multifocal lenses are produced by grinding one face to a spherical curvature and the other to a multifocal curvature, and smoothing and polishing the face of multifocal curvature by elastic means incapable of changing the curvature. In the grinding machine shown, the lenses are mounted in holders on a pair of spindles 10 driven in opposite directions by bands from the shaft of a grinding wheel, 8, of parabolic or spiral, etc., section. The spindles may be moved endways to lift the lenses from the wheel, and they may be retained in the elevated position by collars 15 engaging with cams 16. The smoothing is effected by a rotary tool having a resilient surface covered with chain-mail, as

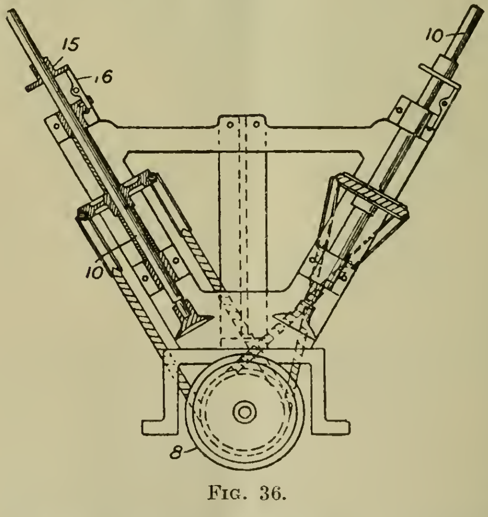


Fig. 36.

described in Specification 111716, and the polishing by a similar tool covered with felt. The resilient surface may be provided by cork or sponge-rubber, or it may be a rubber disc under fluid pressure. H. G. C.

136. Grinding and Polishing Machinery. (Brit. Pat. No. **111716**.) H. P. Gowlland (December 7th, 1916, No. 17607).—Tools for smoothing lenses after grinding consist of an elastic head covered with chain-mail fabric, or having a series of metal buttons secured thereon. The disc 1 mounted on the spindle 13 has clamped round its edge a sheet of elastic material 6, and is provided with means by which fluid may be forced into the space between the disc and the sheet, or a filling of cork or sponge-rubber may be used. The chain-mail fabric is secured over the elastic sheet by means of a clamping ring 10. H. G. C.

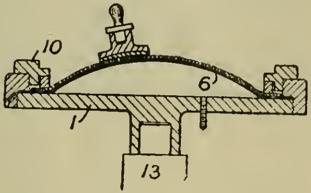


Fig. 37.

137. Machinery for Grinding Glass, etc. (Brit. Pat. No. **112349**). W. Taylor (March 1st, 1917, No. 3045. Addition to 15375/15).—In the application of the method of "terrace grinding" as described in the Patent Specification to the formation of spherical surfaces on glass and like materials, the edge of the abrasive wheel is set so that it moves across the face of the rotating work, there being a slow movement of approach between the work and the wheel, the axes of which are set at the requisite angle to give the required radius. The rough grinding is accomplished with the wheel axis set relatively to the work axis out of one common plane, so that the wheel operates to one side only of the axis of the work. The finishing operation is accomplished by the wheel set with its axis substantially in one plane with the work axis. The annular grinding disc (*e*) is formed with a bevelled surface (e^2) to give the necessary clearance and an active surface (e^3) to give the abrupt step. The disc is carried on a driven spindle (*f*) in bearings in a yoke flame (*h*) supported on aligned pivots (*i*), which are mounted on a slide rest constructed as described in Specification 15377/15. The frame can be tilted about these pivots by a screw (*n*) passing through a nut (*o*) on the frame, to move the axis (e^1) of the grind-

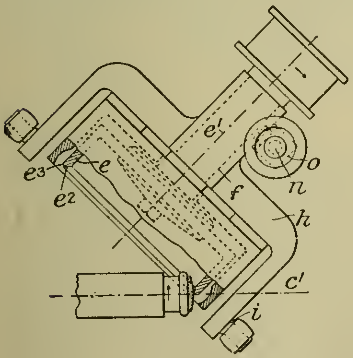


Fig. 38.

ing dish out of the plane of the axis (c^1) of the work spindle. The rough grinding is accomplished with the axis (e^1) set at an angle to the axis of the work spindle. During this operation, the axis is gradually lowered until, for the finishing operation, it is in the plane of the work spindle. The axis of the pivots (i) passes through the axis of the work spindle at the active point of the grinding disc. The work-spindle axis may be tilted in place of the grinding-disc axis. A separate wheel may be used for the finishing operation, and may be mounted as described in Specification 15377/15, and in this case a number of work spindles may be mounted on a turret arranged and operated as described in the same Specification. H. G. C.

X.—Glassware Accessories.

138. Boxes for Packing Electric Lamps. (Brit. Pat. No. **111151**.) A. Astley (November 14th, 1916, No. 16294).—Fittings, internal; partitioned and cellular boxes. In a box or tray for holding electric lamp bulbs, each bulb is held in place by one or two pairs B^1, B^2 of wires, which grip the stem of the bulb, and by a pair B^3 of twisted hemp cords, etc., which grip the large end of the bulb. The wires and cords pass through holes or notches in the partitions shown. H. G. C.

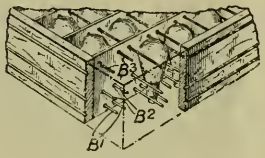


Fig. 39.

139. Bottle Stoppers. (Brit. Pat. No. **111002**). H. B. Fox Bourne (January 20th, 1917, No. 1030).—Slate powder, with or without gas-retort carbon, is used in a rubber composition for hard vulcanised screw-stoppers for bottles. A suitable composition consists of indiarubber 4 parts (by weight), boiled oil 2 parts, sulphur 2 parts, ground slate 39 parts, and carbon black 1 part. H. G. C.

140. Stoppering Bottles, etc. (Brit. Pat. No. **111011**). W. W. Butler and C. W. Flear (February 12th, 1917, No. 2080).—In a machine for inserting screw and like stoppers in bottles, etc., and of the kind in which the screwing spindle is driven through a helical spring, which absorbs any further rotation after the stopper is screwed home, the spindle (a) (Fig. 40) carrying the chuck (b) has its end working through a sleeve (d) which carries the driving pinion (e), and is mounted in an arm or bracket (f), and the coiled spring (g) is connected at one end to the sleeve (d) and at the other end to a plate or collar (g^1) on the spindle (a), to which a chuck (*b*) is secured. Fig. 41 shows a machine with two screwing spindles (*a*) carried by brackets (*f*) disposed about the driving spindle (*h*), and having the pinions (*e*) on the sleeves (*d*) gearing

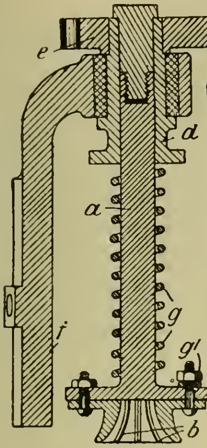


Fig. 40.

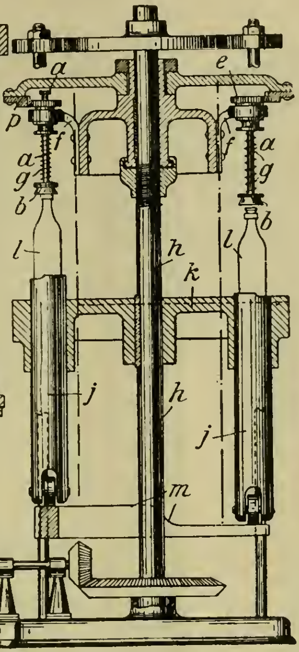


Fig. 41.

with a fixed toothed annulus (*p*). The bottles (*l*) are supported by rests or cylinders (*j*), which are arranged in sleeve parts of the rotating table (*k*), and are raised by a fixed cam (*m*) to bring the stoppers into contact with the chucks (*b*). H. G. C.

Reviews.

Reports of the Progress of Applied Chemistry. Vol. III., 1918. (Published by Society of Chemical Industry. 5*s*. 6*d*. net.)—The third volume of reports has recently come to hand, and despite the omission of the sections on ceramics and building materials, is a very comprehensive review of the whole field of industries based on the science of chemistry. Although some of the sections can only make an appeal to the trained scientific worker, there are others, particularly those dealing with Plant and Machinery, Fuel, Gas, Alkalies and Salts, and Glass and Refractories, which all manufacturers who desire to keep abreast of the time should read.

W. E. S. T.

I.—Glass-making Materials.

141. Separators for Sand. G. F. W. Hope (Brit. Pat. No. **120763**, November 19th, 1917, No. 17029).—In a separator for sand a chamber, 1 (Fig. 42), is divided by a series of screens, 3, which can be removed or reversed without stopping the machine. The screens are introduced into transverse guides, 2, within the chamber through openings in one or both walls, the openings being closed by air-tight doors, 4, held in position by means such as a wingnut. An air-space is arranged around the sides and top of the screens, and the dust-laden air is drawn by a fan or the like, 8, into a settling chamber, 7, or it can be passed back into the grinding mill. A fan, 9, draws the air from the mill or the like into the separator. A device for giving a sharp reciprocating or shaking motion to the screens is provided, such device comprising, for example, a sliding rod, 10, with forks, 11, engaging with the top edges of the screens, the rod being reciprocated by a lever, 12, which is rocked by a connecting rod, 14, from a crank-pin, 15. The upper part, 19, of the chamber, 7, may be expansible under air pressure. Two chambers, 1, preferably are employed, the current of sand-laden air being passed first through one chamber for a time and then shut off from this chamber and passed through the other.

H. G. C.

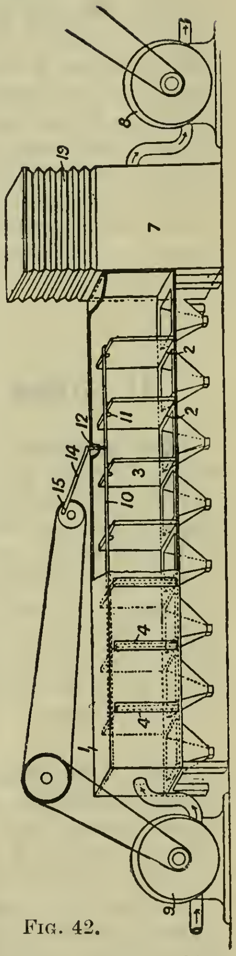


Fig. 42.

142. Preparation of Alumina. J. P. A. Larson and W. D. Bergman, Stockholm (Brit. Pat. No. **120550**, August 26th, 1918, No. 13873. Convention date, October 9th, 1917).—Clay, bauxite, or other natural substances containing aluminium together with iron and silicic acid is treated with sulphuric acid to yield an impure solution of aluminium sulphate. The solution is acted on by a reducing agent such as sulphurous acid or a sulphite to reduce ferric to ferrous sulphate, and is mixed while at 70—100° with ammonium sulphate, allowed to settle at this temperature, and the decanted solution cooled to separate crystals of ammonium alum. The crystals are decomposed by exposing them to ammonia, either gaseous or in solution, to yield ammonium sulphate and aluminium hydroxide, which may be heated to obtain alumina. H. G. C.

143. Preparation of Alumina and Other Materials. E. E. Dutt and P. C. Dutt (Brit. Pat. No. **120838**, March 4th, 1918, No. 3767).—A mixture of calcined clay or bauxite, or both, with calcium or other alkaline-earth chloride is heated to bright redness in a stream of arsenious oxide vapour, producing arsenious chloride, which is decomposed by steam into arsenious oxide and hydrochloric acid, and an aluminate. The residue is dissolved in hydrochloric acid and treated with calcium aluminate to precipitate alumina and re-form calcium chloride, which, after the addition of some lime to precipitate the iron, may be used again. H. G. C.

II.—Glass: Manufacture and Properties.

144. Exhibit of Samples of Glass showing Filming. W. H. Withey (*Trans. Optical Soc.*, 1918, **20**, 40).—Five samples of optical glass were tested, at the National Physical Laboratory, by exposing broken surfaces to a moist atmosphere at 18°, for a week, and estimating, by means of iodeosin, the alkali liberated. Four of them gave excellent results, No. 3 being distinctly inferior. After a further two years' exposure on an open roof, No. 3 was distinctly best. No. 2 was very much more tarnished than No. 1, though it was of similar composition. It was concluded that the iodeosin test alone was not a sufficiently adequate test of filming, and that other tests are desirable. J. R. C.

145. Two Modes of Condensation of Water Vapour on Glass Surfaces. T. Trouton (*Proc. Roy. Soc.*, 1907, *A* **79**, 383.) A cylindrical glass bulb containing glass-wool and connected to a pressure gauge was evacuated. Small quantities of water were admitted into the apparatus at intervals of three days and the pressure observed. It was found that it could be arranged for a glass surface, holding a certain amount of water, to have a smaller vapour pressure than a drier surface; that is, it is possible for a relatively wet surface to act as a drying agent to a drier surface. The analogy of this supersaturation effect with Thomson's curve of transition from vapour to liquid was discussed. The phenomenon occurred at a certain critical pressure, which might be a function of the temperature. J. R. C.

146. The Technique of Optical Glass Melting. C. N. Fenner (*J. Amer. Cer. Soc.*, 1919, **2**, 102).—The author dealt with the melting process and allied operations in the sequence in which they occur in practice.

As regards preliminary operations, the following points were emphasised: (*a*) the necessity for pure raw materials free from metallic oxides which impart colour, such as those of iron, nickel, and manganese, and free from such impurities as sulphates and chlorides, which tend to produce opalescence in glass; (*b*) the necessity for thorough mixing, avoiding iron tools; (*c*) the necessity for care in choice of ingredients. For mixing it was recommended that long, open, wooden boxes be used of such capacity that the whole batch may be shovelled from a pile at one end to a pile at the other, using flat wooden paddles or grain-scoops for the purpose. Sifting of all batch ingredients before adding to the batch, and sifting of the mixed batch were recommended.

In connection with the substitution of sodium for potassium compounds and the choice of suitable potassium compounds, the sulphate of potassium was unsuitable because of its tendency to segregate as a layer of "salt water" on top of the melt and because it had the effect, even in small quantities, of inducing milkiness in some glasses. The chloride was rejected for similar reasons and also because of its volatility. Commonly, most of the K_2O was added in the form of carbonate with about 25 to 33 per cent. as nitrate. The nitrate had the highly desirable function of producing oxidising conditions during the thermal dissociation and recombination of the batch ingredients. There was danger that the nitrate, if used in larger quantities than those suggested, would at comparatively low temperatures, be decomposed into a highly caustic liquid likely to attack the pot.

Since sodium compounds were ordinarily cheaper than potassium compounds the extent to which substitution of the former for the latter could be carried was carefully investigated. The use of a certain amount of soda appeared to be desirable, as it probably increased fluidity, but large quantities increased the colour, particularly of glasses high in lead or barium. In a baryta flint glass containing about 38 per cent. PbO, 6·5 per cent. BaO, and 3 per cent. ZnO, the author introduced Na_2O and K_2O in the ratio of 1 to 1·18. The colour of the glass was distinctly greater than when the whole of the alkali used was K_2O. Other evidence was obtained of the colour-inducing effect of Na_2O.

In the author's opinion it was unlikely that the soda itself gave colour, but that the effect was secondary. Possibly a large quantity of soda caused greater corrosion of the pot and led to a larger amount of iron in the glass; or the same amount of iron might show up more in a soda glass, or again the soda used might contain a small amount of sulphide or other material which reduced more of the iron to the ferrous form, thus exerting a more powerful colouring effect.

With most of the raw materials the size of grain appeared to have little effect on melting. With sand, however, a coarse grain increased the length of time for melting, there being greater opportunity for liquation of the easily fusible materials, leaving the quartz floating on top. Slow melting was likely to mean poor fining.

The large quantity of glass rejected owing to optical and other defects represented considerable monetary value, and the author considered the manner in which this cullet might be used. Glass rejected owing to opalescence, bubbles, or striæ might be used; in fact, any glass with defects which could be removed by re-melting might be used. There was no difficulty arising from the use of almost any quantity of cullet. The actual amount used should be decided by the way in which the properties of the cullet corresponded to those of the glass being made. On the other hand, certain properties of the glass would be affected at each re-melting. It would take up more and more iron and other material from the pot, and selective volatilisation would also affect the refractive index. For ease of handling the cullet should be broken up so as to produce a shaly mass.

As a preliminary to melting, the pot was heated to, and allowed to remain at, 1400° for one hour. The pot was then glazed with cullet, the object being to have the pores filled with material of the same composition as the glass to be made. At least three or four scoopfuls of cullet should be used, and it was best to pour it round the inside of the pot and allow it to run down to the bottom. The pot should then be allowed to stand for one hour longer. By maintaining the furnace for two hours at 1400° before starting to fill in the batch proper, all parts of the furnace and regenerative chambers should become well heated, and the heat would have penetrated the furnace lining to such a depth as to make available a certain store of heat for aiding in a quick melting of the batch. The quicker the batch melted down the more satisfactory was the fining likely to be. The normal first addition of batch should half fill the pot with unmelted batch. If the glass was apt to give trouble in fining it was well to reduce the amount of batch added at a time. When the first filling had melted to a level surface (or in about three hours) a second filling of the same quantity was put in and three hours later a third filling. Then one after another smaller additions were made, and finally the melt topped off by a few scoopfuls of batch. The level at which filling ceased should be that at which the melt was an inch or an inch and a half below the rim of the pot.

On the whole, the melting process was rather quiet. The presence of nitre insured that the conditions shall be oxidising, and the furnace atmosphere must not be allowed to reach a stage which involves reduction. The combination of the basic oxides with silica was likely to be slow, and as the silica was of relatively low specific gravity, this gave an opportunity for gravitative differentiation. In flint glasses especially a surface layer containing large quantities of grains of undissolved silica was likely to persist for a long time. In very dense flints a bottom layer of excessive lead content was also formed. As an example of this differential melting, a glass, intended to have a refractive index of 1·648, showed, because of improper stirring, at the bottom a distinct layer, of about a foot in thickness, of glass of a pale greenish-yellow colour, having an index of about 1·690; above this a mass of glass in which the index varied from 1·630 in the lower portions to 1·610 in the upper. During the melting of this glass samples from the top had shown quantities of silica grains embedded in a glass having an index of about 1·545. Probably in most cases a glass of this kind had undergone a similar segregation, but in this example the subsequent procedure was faulty and the segregation was not destroyed by stirring. Possibly, also, in this case the fillings were not given time to melt down sufficiently before others were added. In the author's opinion, if the mixing were sufficiently thorough, a homogeneous solution should be formed.

The author considered that in most cases it was possible to dispense altogether with fining as a separate process. The glass was given a hand-stirring before the melting was really complete, and then, a short time after the last fill, the machine stirrer was set in operation and stirring continued until the pot was ready for removal. During fining the temperature must be kept as uniform as possible.

For most of the common types of glasses a temperature of about 1400° during melting and fining was required. It was essential, however, to see that the temperature did not rise appreciably higher than this, as excessive temperatures were injurious to the pot and increased the amount of selective volatilisation. The following data, given by Zschimmer as the melting temperatures used at the Jena works, were quoted:—

1000° Phosphate glass ($3B_2O_3$, $70{\cdot}5P_2O_5$, $12K_2O$, $4MgO$, $9Al_2O_3$, $1{\cdot}5As_2O_3$ according to synthesis).
1100° Dense lead silicate glass ($20{\cdot}8SiO_2$, $79PbO$, $0{\cdot}2As_2O_3$).
1130° Borate glass ($52{\cdot}5B_2O_3$, $1SiO_2$, $1{\cdot}5Na_2O$, $1{\cdot}5K_2O$, $6ZnO$, $12BaO$, $16PbO$, $9Al_2O_3$, $0{\cdot}5As_2O_3$).
1320° Dense barium borosilicate glass ($14{\cdot}5B_2O_3$, $39SiO_2$, $41BaO$, $5Al_2O_3$, $0{\cdot}5As_2O_3$).
1370° Ordinary flint glass ($45{\cdot}7SiO_2$, $1{\cdot}5Na_2O$, $7{\cdot}1K_2O$, $45{\cdot}4PbO$, $0{\cdot}3As_2O_3$).
1410° Ordinary crown glass ($2B_2O_3$, $69{\cdot}2SiO_2$, $8Na_2O$, $11K_2O$, $4CaO$, $3{\cdot}5ZnO$, $2PbO$, $0{\cdot}3As_2O_3$).

The author discussed at length the origin of bubbles. The great majority of bubbles were, in his opinion, doubtlessly entrapped mechanically, but others appeared to be set free from solution in the glass, particularly during stirring and cooling. To assist in removal of bubbles entrapped mechanically, the author recommended ammonium nitrate wrapped in paper so as to form a package. The fact that the vaporisation of this substance was complete and without residue and that the gas was oxidising in character, made this material almost ideal for the purpose. Other bubbles appeared to consist of gas which had been in solution at a high temperature and had been evolved on cooling. The author found that in some cases, after care had been taken to eliminate all other possibilities and the glass had become free from bubbles during fining, nevertheless, in the subsequent cooling during stirring, bubbles had reappeared and had persisted to the end. Crown glasses containing barium in small to moderate quantities appeared specially prone to dissolve gas and later evolve it as bubbles. Still another class of bubbles, which might be termed vacuum bubbles, appeared when glass was cooled quickly, causing a rigid crust to form over the surface while the interior was still hot. In such a glass, even minute bubbles became enlarged as the glass contracted from them, so that ultimately it might appear full of large bubbles. If, however, the glass were carefully heated to the softening temperature the bubbles collapsed until they were invisible or nearly so.

The author also discussed the function of arsenic in glass melting and suggested that bubbles of arsenic vapour not only gathered up gases which had already been set free as bubbles, but that they collected potential bubbles. Zschimmer's tables showed that at the Jena works the amount of As_2O_3 ordinarily put into the batch was about 0·3 per cent. of the weight of the glass. The author used about the same amount or a little more.

Adequate temperature control was considered by the author to be the most effective means of reducing leakage losses. Emphasis was also laid on the necessity for careful treatment of the pots used, as well as of their construction.

Care was also necessary in skimming to prevent material from the surface being forced down into the metal, whilst too much glass should not be removed during the operation. The composition of the surface layer immediately after fining did not represent the average composition of the melt, and the greater the quantity of glass removed the more the average composition of the whole was changed.

The type of stirring machine employed and the alterations of speed and radius of stirring motion were dealt with in detail; whilst the temperature charts and records of operations made during typical runs were also reproduced. The temperatures at which stirring should cease with different glasses are stated as:

Borosilicate crown	1050°
Light crown	1150°
Baryta flint	980°
Medium flint	950°
Light flint	925°
Barium crown	1025°

The percentage equivalents of batch compositions used by the author in the preparation of a series of optical glasses were as follows:

	Medium flint. n_D=1·605 ν=37·6	Baryta flint. n_D=1·619 ν=37·6	Light crown. n_D=1·516 ν=60·0	Borosilicate crown. n_D=1·511 ν=64·1	Light flint. n_D=1·580 ν=41·1	Barium crown. n_D=1·570 ν=57·0	Dense flint. n_D=1·640 ν=34·6
SiO_2	47·94	43·80	71·56	70·04	52·72	48·85	41·68
PbO	42·38	38·12	—	—	35·03	—	50·52
K_2O	5·07	8·32	9·01	12·02	5·54	4·30	3·50
Na_2O	4·32	—	8·08	7·44	6·32	4·31	4·00
ZnO	—	3·05	—	—	—	8·91	—
BaO	—	6·47	2·61	—	—	28·57	—
B_2O_3	—	—	—	8·30	—	3·75	—
CaO	—	—	8·02	1·92	—	—	—
Al_2O_3	—	—	—	—	—	1·01	—
As_2O_3	0·29	0·26	0·72	0·28	0·39	0·30	0·30

In the author's view, the process of optical glass production must be treated as a laboratory operation carried out on a large scale, and must provide for attention to each pot individually as its requirements demand. F. W. H.

147. An Improved Method of Optical Glass Manufacture. G. W. Morey (*J. Amer. Cer. Soc.*, 1919, **2**, 146).—The author gave an account of modifications made in the usual furnace operations at the works of the Spencer Lens Company, which produced better glass with a doubling of output and correspondingly lower cost as the result of the new methods adopted.

The author stated that the melting of the batch takes place from the top downwards; the upper layer sinters together, then the more easily fusible components trickle down, leaving the upper layers impoverished in the substances usually called "fluxes." This results in the surface becoming rich in silica. Both flint and crown batches showed not only an actual accumulation of partially dissolved quartz grains, but also had a refractive index lower than that of the rest of the glass.

The fluxes, especially lead, tend to settle to the bottom. In the usual process this lead-rich layer was allowed to lie on the bottom of the pot throughout the filling and fining periods, resulting in greatly increased pot corrosion with all its attendant dangers. In addition, the impoverishment of the upper layers in fluxes increased the time required for complete solution of the batch ingredients.

This trouble, and also the question of removal of bubbles, the author suggested, may be overcome by hand-stirring during filling and commencing machine-stirring immediately after the fill, followed by stirring continuously, instead of allowing the glass to stand for fining and then stirring intermittently.

A sample schedule was given for a flint glass having $n_\mathrm{D}=1\cdot617$, $\nu=36\cdot5$, the pot used being 26 inches high and 28 inches in diameter, inside dimensions. The time of filling on cullet was taken as starting point.

Time—hours.	Run at 1390°.
0 : 00	Add cullet.
1 : 00	Fill pot three-quarters full of batch.
2 : 30	Fill pot with batch.
4 : 00	Hand-stir ; fill pot with batch.
5 : 30	,, ,,
7 : 00	,, ,,
7 : 30	Stirring-machine on.
15 : 00	Gas off.

F. W. H.

148. The Variation of the Transparency of Glasses to Ultraviolet Light with their Chemical Composition. E. Zschimmer (*Phys. Zeitschr.*, 1907, **8**, 611).—In order to obtain chemically pure glasses the melts were made in platinum crucibles and the purest materials used. Pieces of the glasses so obtained were carefully annealed, ground into plates and polished, and examined by means of a quartz-fluorspar spectrograph. Electrodes of Mg, Cd, Zn, and Al were used to obtain an ultraviolet spark spectrum. Sometimes, also, other lines were observed, and these were ascribed to the fluorescing of the glass. The results obtained are as follows:—

Glass No.	Synthetic chemical composition.	Wave-length in $\mu\mu$ up to which the glass was transparent, and the thickness of the plate.	
V.S. 1450...	B_2O_3.	186 in 3 mm.	
V.S. 1456...	$85B_2O_3,15Na_2O$.	186 ,, 3 ,,	faint.
V.S. 2161...	$74B_2O_3,26Na_2O$.	226 ,, 3 ,,	good.
V.S. 2164...	$70B_2O_3,30Na_2O$.	275 ,, 2 ,,	good.
V.S. 1676...	$79B_2O_3,21K_2O$.	199 ,, 3–4 ,,	faint.
V.S. 1453...	$41B_2O_3,59ZnO$.	245 ,, 3 ,,	good.
V.S. 1677...	$57B_2O_3,43BaO$.	210 ,, 3 ,,	faint.
V.S. 2159...	$50B_2O_3,50BaO$.	231 ,, 4 ,,	good.
V.S. 1674...	$64B_2O_3,12Na_2O,12K_2O,12BaO$.	245 ,, 2 ,,	good.
V.S. 1675...	$40B_2O_3,55BaO,5Al_2O_3$.	280 ,, 3 ,,	good.
V.S. 2938...	$25B_2O_3,65BaO,10Al_2O_3$.	280 ,, 5 ,,	faint.
V.S. 1671...	$66B_2O_3,30CaF_2,4Al_2O_3$.	226 ,, 3 ,,	good.
V.S. 1700...	$56B_2O_3,40CaF_2,4Al_2O_3$.	257 ,, 3 ,,	good.
V.S. 2524...	$40B_2O_3,60BaF_2$.	257 ,, 2½ ,,	good.
V.S. 2022...	$40B_2O_3,50BaO,10PbO$.	346 ,, 3½ ,,	good.
V.S. 2139...	$\left\{\begin{matrix}22B_2O_3\\58SiO_2\end{matrix}\right\}5Na_2O,15K_2O$.	275 ,, 4 ,,	good.
V.S. 2944...	$\left\{\begin{matrix}25B_2O_3\\15SiO_2\end{matrix}\right\}15ZnO,45BaO$.	275 ,, 5 ,,	faint.
V.S. 2191...	$78SiO_2,22K_2O$.	245 ,, 3 ,,	faint.
V.S. 2182...	$68SiO_2,32K_2O$.	275 ,, 3 ,,	good.

The conclusion was drawn that the high transparency of pure B_2O_3 and SiO_2 decreased with increasing addition of metallic oxides, although the latter are not equally effective in increasing the absorption. K_2O had less effect than Na_2O, whilst PbO caused strong absorption. The author stated that these results were only of directive value, as none of the glasses enumerated was sufficiently durable or capable of production in large quantities free from small bubbles.
J. R. C.

149. The Electrical Conductivity of Soda-Lime-Silicate Glasses. R. Ambronn (*Ann. Physik*, 1919, **58**, 139).—A fuller account of the experiments referred to in this Journal, 1918, Abs. 240. The difficulty of finding suitable electrodes, mentioned in the previous paper, was discussed at length. Finally, "burnt-in platinum" electrodes were made by covering the finely ground glass surface with a platinum solution and heating this to about 500° for two hours. The platinum covering so obtained gave good contact with the glass. Measurements were made at temperatures up to 450°, both while raising the temperature and again when it was falling. In the former case the conductivity was always greater than in the latter. This was considered to be due to a polarisation effect arising from the migration of the sodium ions to the electrodes.

The conclusions drawn from the experiments confirm those previously made. Assuming that the conductivity can be expressed in the form $L = L_{\alpha} e^{-\beta/\theta}$ where L_{α} and β are constants, depending on the chemical composition of the glass, and θ is the absolute temperature, the formula gives an accurate representation of the results within the limits of experimental error. For the lime–soda–silicate glasses the complete expression is:

$$L = (12{\cdot}58c + 7{\cdot}515k - 214{\cdot}68)e^{\frac{-9803{\cdot}7 - 59{\cdot}045c + 174{\cdot}00k - 3{\cdot}4040ck}{\theta}},$$

c being the percentage, by weight, of Na_2O in the glass and k that of CaO. The values of L_{α} and β from which these constants were evaluated are appended. Two specimens were examined in each case.

No. of glass.	Percentage composition.			L_{α}	β.
	Na_2O.	CaO.	SiO_2.		
4	22	8	70	124·2	9292·1
				123·8	9314·0
5	34	8	58	262·2	8210·6
				300·0	8275·1
6	15	12	73	69·65	10455·9
				69·86	10473·0
7	22	12	66	151·2	9724·4
				147·8	9726·9
8	28	12	60	249·3	9022·6
				203·3	8888·9
9	12	16	72	51·81	11120·0
				52·12	11109·4
10	20	16	64	134·1	10258·2
				155·6	10350·7
12	20	20	60	197·2	10819·8
				213·1	10816·6
13	36	4	60	265·7	7924·3
				273·1	7933·3

J. R. C.

150. The Occlusion of the Residual Gas by the Glass Walls of Vacuum Tubes. A. A. Campbell Swinton (*Proc. Roy. Soc.*, 1907, *A*, **79**, 134, and 1908, *A*, **81**, 453).—It was found that the walls of vacuum tubes, employed for some investigations in 1898, were roughened where the glass had been exposed to the bombardment of the cathode rays. When the glass was heated it became clouded, the effect being due to minute, spherical bubbles in the glass. Investigation showed that these were at a depth of 0·122 mm. from the surface. It was ascertained that the gas was hydrogen and that the occlusion was due to the mechanical driving in of the gas into the glass and not to any chemical combination.

In the second paper the author dealt with comments on his previous conclusions. J. J. Thomson suggested that the glass was heated by the bombardment of the cathode rays, thus allowing the gas to diffuse into the glass. It was shown that, although the original depth of the bubbles was only one-tenth of that previously measured (the heating causing the gas to travel inwards), the glass did not become hot enough during the discharge to permit diffusion Other suggestions were considered, but the author reiterated his former views. J. R. C.

151. The Lime-Silica Series of Minerals. A. L. Day, E. S. Shepherd and F. E. Wright (*Amer. J. Sci.*, 1906, **22**, 265).—The authors state that only one well-defined mineral of this series is known, although, according to Boudouard, the freezing-point curve for the lime–silica system showed four eutectics and three maxima, which corresponded to the meta-silicate, the ortho-silicate, and the tricalcic silicate These results were criticised owing to the adoption of Seger cones as the method of temperature measurement.

Continuing their experiments on the lime–silica series, the authors found that there were only two definite compounds of lime and silica capable of existing in contact with the melt, namely, (1) the pseudo-hexagonal metasilicate, melting at 1512°, and undergoing inversion to *wollastonite* at 1200°. This metasilicate is capable of taking up in solid solution a small amount of either lime or silica; (2) the ortho-silicate of calcium, melting at 2080° and possessing three polymorphic forms. The α-form crystallised in the monoclinic system and had a density of 3·27; the β-form in the ortho-rhombic system with a density of 3·28; and the γ-form, also in the monoclinic system, with a density of 2·97. The disintegration of the orthosilicate, and of all lime–silica mixtures containing more than 51 per cent. of lime, was due to the 10 per cent. volume change accompanying the $\beta \rightleftarrows \gamma$ inversion. The inversion point α to β was at 1410°; $\beta \longrightarrow \gamma$ at 675°. There were three eutectics in the series, namely, *tridymite* + the metasilicate at 37 per cent. CaO, 1417°; the metasilicate + the orthosilicate at 54 per cent. CaO, 1430°; and the orthosilicate + lime at 67·5 per cent. CaO, 2015°. The orthosilicate was readily attacked by water, which dissolved out the lime in large quantities.

Optical evidence, gained by the microscopic study of the crystallised products of mixtures of silica and lime, confirmed these findings, and also indicated that the metasilicate formed solid solutions with the orthosilicate as well as with lime and silica. J. R. C.

152. Wollastonite and Pseudo-Wollastonite. E. T. Allen and W. P. White (*Amer. J. Sci.*, 1906, **21**, 89).—In connection with a study of the *pyroxenes* it was desirable to prepare *wollastonite* and determine its properties. For this purpose a glass of the composition $CaSiO_3$ was made. The purest quartz and calcium carbonate were used and melted in a platinum crucible, a temperature of over 1500° being necessary. The molten glass thus obtained had a strong tendency to crystallise spontaneously, *pseudo-wollastonite* being formed. However, if, when the contents of the crucible were quite fluid, the latter was plunged into cold water, a brilliant, colourless glass was obtained. The glass was then heated in a platinum crucible over a Bunsen burner to a temperature of from 800° to 1000°, when it crystallised directly to *wollastonite*. The authors state that, in their opinion, *wollastonite* cannot be formed in a glass melt at a temperature above 1180° The average specific gravity of glass of the composition $CaSiO_3$, determined at 25°, was given as 2·904. J. R. C.

153. Minerals of the Composition $MgSiO_3$. E. T. Allen, F. E. Wright, and J. K. Clement (*Amer. J. Sci.*, 1906, **22**, 385).—A continuation of the general investigation referred to in abstract No. 151. It was found that there were four crystal forms of magnesium metasilicate, two of which occurred in nature, usually in mixed crystals with ferrous silicate. The first type, a monoclinic *pyroxene*, is formed by crystallising a melt of glass of this composition a little below the melting point (1521°), or by heating any form of the metasilicate to about 1000°, in molten magnesium chloride, traversed by a stream of hydrogen chloride. All the other forms passed into this one at temperatures between 1150° and 1300°. Crystals of the second type, ortho-rhombic *pyroxenes*, were made by heating the metasilicate glass to a temperature between 1000° and 1100°. The third crystalline form was a monoclinic modification corresponding to an *amphibole* in its optical properties. It was formed in very minute quantities when the glass melt was rapidly cooled. Form four was ortho-rhombic, very similar to the previous form, and was obtained by heating the molten silicate beyond the melting point (to 1600°) and then cooling rapidly in air; it could not be formed by heating the solidified glass.

Of the four polymorphic forms, the first was stable at all temperatures. The specific gravities at 25° were 3·192, 3·175, not determined, and 2·857 respectively. The experiments did not settle the uncertainty of the formation of unstable bodies, but they showed that temperature and viscosity were factors of prime importance. From glass melts, or silicate solutions, the stable monoclinic form of $MgSiO_3$ crystallised at the highest temperatures and the *amphiboles* at lower ones. J. R. C.

III.—Lamp-worked and General Scientific Apparatus.

154. A Device for Removing Plugs from Stopcocks. V. C. Allison (*J. Ind. Eng. Chem.*, 1919, **11**, 468).—A common method employed to remove a stopcock key that has stuck is to place a small piece of wood on the end of the plug and to hammer till the plug is free. This often results in cracking the barrel or in chipping the key, and, in complex apparatus, in the breakage of important parts. If, however, a steady pressure is exerted on the plug with the glass in contact with

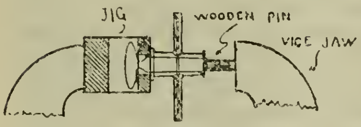


Fig. 43.

nothing but wood, it can easily be removed without any damage to any of the parts.

A piece of hard wood is cut so as to allow the key of the stopper to pass freely through a hole which is not large enough to allow the barrel to pass (Fig. 43). A short hard wood pin is placed against the smaller end of the plug, and the whole is put between the jaws of a vice, which on being closed exert a strong, steady pressure. It is claimed that by this means stopcocks can be quickly removed without breakage. S. E.

155. The Use of Standard Dies in Making Ground Glass Joints. S. F. Acree (*J. Ind. Eng. Chem.*, 1919, **11**, 338).—In view of the importance of ground glass joints, it is urged that a uniform taper should be adopted for all stoppers, stopcocks, etc. If such a standard taper and size were adopted, replacement of broken parts of apparatus would be very much facilitated. The angle of the morse taper corresponds to a general decrease in diameter of 0·625 in. per foot, and is nearly ideal for ground glass joints. At the present time there are eight different sizes of these standard tapers available, and although they do not completely overlap, the gaps are so small that practically any diameter of ground glass joint can be obtained.

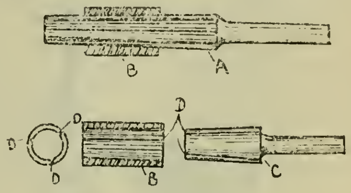


Fig. 44.

The morse taper *A* (Fig. 44) can be used for making a tool steel collar, *B*, which is used for grinding the outside of the key. The grooves *D* in *B* and *C* hold the emery during grinding. The sets of such tools should be made and labelled 1, 2, and 3. No. 1 should be used for rough grinding, No. 2 for fine grinding, and No. 3 for finishing. Since the wear on No. 1 will be much greater than on 2 or 3 it will lose its shape first, and when it has become worn too badly it should be replaced by No. 2. No. 2 is replaced by No. 3, and a new No. 3 made to complete the new set.

These dies, it is stated, do not wear out rapidly under erosion by carborundum or emery, and the method has been found to be very satisfactory. S. E.

156. The Permanent Marking of Glass Vessels. J. C. Bock (*J. Amer. Chem. Soc.*, 1919, **41**, 359).—According to the author, glass vessels may be marked by a process very similar to that used in painting on glass. A suitable colour consisting of a mixture of low-melting silicates and colouring oxides is intimately mixed with a vehicle (4 parts copaiba balsam, 1 part clove oil, 1 part lavender oil), until it is of such consistency as to run from a pen. The desired markings are made on a clean glass surface, and the article warmed so as to dry the oil. The place where the marking has been made is heated by holding against the side of a flame. The mark first turns black, due to the carbonisation of the oils, and then begins to glow at a dull red. At this stage the article is removed and allowed to cool a little, after which the marking is again heated until it begins to glow.

The mark so obtained presents a smooth, shiny surface, and cannot be removed by either mechanical or ordinary chemical means. Microscope slides can easily be marked by this method, but they should be heated in a muffle so as to avoid breakages. S. E.

157. A Simple Form of Apparatus for Estimating the Oxygen Content of Air from the Upper Atmosphere. F. W. ASTON (*Trans. Chem. Soc.*, 1919, **115**, 472).—The samples of air to be analysed are contained in test tubes holding rather more than is necessary for the analysis and in which a little potassium hydroxide has been fused to remove carbon dioxide and water-vapour. The measuring burette and barometer tube (Fig. 45) are normally kept full of mercury. In order to carry out an analysis the capillary stopcock *B* is closed and the reservoir *C* lowered until the level of the mercury in the barometer tube is a little below its upper and broader part. The stopcock *A* is then closed and the sample tube held down over the inverted syphon tube in the mercury trough *D*. The stopcock *B* is opened, and the air flows into the upper part of the burette, when the mercury rises to the top of the barometer tube. The sample tube is removed, and by opening *A* and lowering the mercury reservoir *C*, mercury is drawn in to fill the capillary tube and the stopcock *B* is turned off.

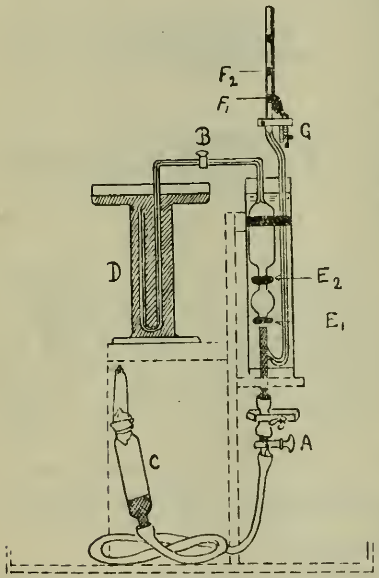


FIG. 45.

The volume of air thus introduced is constant, being that of the volume of the upper part of the barometer tube, the pressure being atmospheric plus the small difference in level between the top of the syphon tube and the mercury in the trough. This quantity is now accurately measured, and the air is then forced into a quartz test-tube containing a pellet of phosphorus, which on burning completely removes all oxygen. The nitrogen is returned to the burette, and the pressure measured at a definite volume. S. E.

158. On the Determination of Boiling Points of Solutions. F. G. Cottrell (*J. Amer. Chem. Soc.*, 1919, **41**, 721).—The usual methods of determining the boiling point of a solution are regarded by the author as very unsatisfactory, the chief difficulty being that the thermometer must be placed in the liquid and consequently be affected by the superheating of the solution. The novel feature of the method described consists in placing the thermometer bulb in the gaseous phase, as in the case of a pure liquid, and making the boiling of the liquid pump some of the solution over it in a thin film, thus duplicating the same relations of vapour, liquid, and thermometer which ordinarily obtain in the determination of the boiling points of pure liquids.

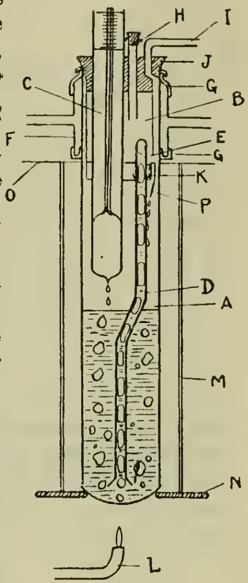


Fig. 46.

A simple and easily constructed form of apparatus for doing this is shown in Fig. 46, in which *A* is a large test-tube, *B* a flat-bottomed specimen tube in the base of which two holes have been blown. Through these holes loosely pass the Beckmann thermometer *C* and the pump tube *D*, the thermometer as well as the tube *B* being entirely supported by the stopper *J*, while the tube *D* rests upon its shoulder *K*. As an alternative to this shoulder, a few turns of stout platinum wire may be wrapped round the tube. Another hole *E* is also provided in the side of *B* farthest from *C* to produce a balance between *A* and *B*, and to act as an overflow, thus fixing the level of the liquid in *B*. The water-jacket *F* secured by the rubber tubing *G* to the upper part of *A* forms with the latter a reflux condenser. The tube *H* serves for the introduction of the solute, and the tube *I* connects by means of a number of radiating channels through the stopper *J* with the annular condensing space between *A* and *B*. The portion of the boiling tube lying below the condenser may advantageously be protected from air currents by a wide glass tube *M*, resting on the asbestos plate *N* and covered by the mica sheet *O*.

When the liquid in *A* is boiling, part of the bubbles of vapour pass up the tube *D*, carrying a broken stream of liquid with them into *B*. The proper diameter of the tube *D* depends on the nature of the solvent used; for liquids such as ether or carbon disulphide it should be about 2 mm., but for liquids with a higher surface tension, such as water, it should be 4 mm.

The author believes that the use of this apparatus will considerably reduce any errors due to superheating, and make the boiling-point method of determining molecular weights at least as accurate as the freezing-point method. S. E.

159. A Scrubber for Ammonia Distillations. B. S. Davisson (*J. Ind. Eng. Chem.*, 1919, **11**, 465).—Two of the most important errors encountered in ammonia distillations are those due to the entrained alkali and the soft glass used in the construction of distilling bulbs and adapters. The error from the solubility of the soft glass can be eliminated by using apparatus made of Pyrex glass, which has been found to be very satisfactory.

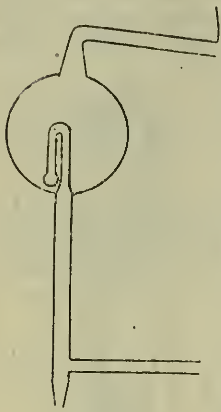


Fig. 47.

A distillation scrubber as shown in Fig. 47 has been found efficient in preventing alkali being carried over with the steam. The large bulb has a capacity of 200 c.c., which gives a satisfactory condensing surface. The small bulb on the inlet tube has three openings in the same horizontal plane.

The first steam passing into the bulb condenses, and, in flowing through the small bulb, acts as a scrubbing solution for the remaining vapours. As soon as this water becomes hot it is subjected to a long period of steam distillation, thus removing all the ammonia. For delivery of the condensed liquid a special adapter with a perforated bulb is recommended. S. E.

IV.—Decorated Glass.

160. A Method of Depositing Copper on Glass. F. D. Chattaway (*Proc. Roy. Soc.*, 1907, *A*, **80**, 88).—The close relation of copper to silver led to the conclusion that it should be capable of deposition in the same way. The author found that phenylhydrazine served as a suitable reducing agent, and the following method of employing it was recommended. A mixture of one part of freshly-distilled phenylhydrazine and two parts of water is heated until a clear solution is obtained. To this about half its bulk of a warm saturated solution of cupric hydroxide in strong ammonia is added. The cupric salt is reduced to cuprous hydroxide, which remains dissolved in the ammoniacal liquid, and does not undergo any further appreciable reduction till heated. A hot 10 per cent. solution of potassium hydroxide is next added until a slight permanent precipitate of cuprous hydroxide is produced. If this colourless or pale yellow liquid be cautiously heated in contact with a perfectly clean glass surface, metallic copper is deposited upon it in the form of a thin, coherent, perfectly reflecting film.

The nature of the surface on which the metal was deposited played an important part in the process, since both silver and copper were deposited much better on blown than upon polished glass, and upon surfaces which had not for long been exposed to the action of the air or of water. The author considered it probable that the glass surface acted as a catalyser and locally accelerated the action.

J. R. C.

V.—Optics and Optical Instruments.

161. Two-Lens Combinations. T. Chaundy (*Optician*, 1919, **56**, 276).—The Gaussian first order geometry of a lens system, whilst enabling the first order properties of a chosen system to be determined, helped little towards the choice of a system possessing stipulated properties. The author, in this paper, dealt with the case of a pair of separated thin lenses. He showed that the "shape" of an optical system, as opposed to its "size," depends on the ratio of the distance between the principal points, to the focal length of the combination. An expression for B, the value of this ratio, in terms of the powers of the two lenses, and the distance between them, was derived, and examples given of the use of curves plotted, from this relation with the powers of the lenses as co-ordinates. Since the condition of achromatism was a function of the same variables, it could be determined, whether achromatism was or was not possible with a given combination. The results were arrived at on the assumption that the power of the combination was positive; but the author indicated the manner in which the method could be applied to the reverse case. J. R. C.

162. Some Generalised Forms of an Optical Equation. T. Smith (*Trans. Optical Soc.*, 1918, **20**, 23).—The equation for refraction at a spherical surface, upon which the general theory of image formation in optical instruments is based, applies strictly only to paraxial rays. In this paper the author showed how the equation may be modified, by the inclusion of an additional factor, so as to be applicable to all rays. The modification did not lead to an exact method of ray tracing, but it enabled the departure from the paraxial law at any surface to be estimated to a considerable order of accuracy.

All the angles required to specify a ray could be expressed in terms of three angles, some one of which vanished when the rays passed through any one of the three pairs of conjugate points at which there was freedom from aberration. The additional factor to be introduced was the product of the tangents of the halves of any two of these three angles, and three exact equations of refraction were thus found. The correcting factor had only to be known approximately to enable the refraction of the ray to be determined to a high order of accuracy. When rays were to be traced through a series of surfaces the most convenient form of the equation at each surface was $\mu'/(x'-p)-\mu/(x-p)=(\mu'-\mu)/(r-p)$, where p was to be regarded as a correction to the radius of curvature and as a displacement of the effective unit points.

A number of illustrative calculations formed an appendix to the paper, and the results obtained were compared with the values derived by tracing rays through the system. The method, it was suggested, should prove convenient in studying eyepieces and other systems in which the obliquity of a ray to the axis was very large.
J. R. C.

163. Spectacle Lens Blemishes. J. Scott (*Optician*, 1919, **57**, 165).—The author described the microscopical appearance of some blemishes on glass surfaces, including the ordinary scratches of "herring bone" appearance, and "glass flaws" similar to the etch effects described by Quincke (this Journal, 1918, Abstr. No. 83). It is stated that crystals of *wollastonite* have been found in a glass, forming a centre from which fine cracks radiate. The appearances described are illustrated. J. R. C.

164. The Spherical Aberration of a Thin Lens. T. Y. Baker and L. N. G. Filon (*Trans. Optical Soc.*, 1918, **20**, 58).—The Gaussian equations for the determination of the size and position of the image of a small object, formed by a thin lens, were not exactly satisfied as the rays are not paraxial. One of the defects of the image due to the departure from these equations was spherical aberration, which, if good image formation was required, must be made as small as possible. Curves of the first order caustic for different image positions were plotted, and it was shown that there was only a limited range of image positions for which over-correction of spherical aberration was possible, and that the amount of over-correction was minute. There was a physical limit beyond which the over-correction must not be applied, or it would be impossible to manufacture the lens. J. R. C.

165. An Empirical Formula for the Longitudinal Spherical Aberrations in a Thick Lens. T. Y. Baker and L. N. G. Filon (*Trans. Optical Soc.*, 1918, **20**, 67).—The authors showed that a formula of the type $q=At_4'/(1+Bt_4'^2)$, where t_4' is the tangent of the angle made with the axis by the Gaussian ray which passed through the geometrical image, provided a rapid and practically accurate method of obtaining the longitudinal spherical aberration in a lens, without the use of laborious trigonometrical calculations. J. R. C.

166. The Eikonal. A. Pelletan (*Journal de Physique*, 1907, **6**, 782).—The author pointed out that construction of optical instruments had given rise to mathematical investigations which had lead to many practical results. The author stated that little attention had been paid in France to the calculation of the elements of an optical system by modern methods, and he therefore gave a summarised account of the theory of geometrical optics. Its development was traced from Gauss's researches to Hamilton's "characteristic function." The function known as the Eikonal was then defined and applications of it considered. The various aberrations were discussed, and the paper concluded with a chapter on objectives. J. R. C.

167. A New Half Shade Polarimeter. L. Zehnder (*Ann. Physik,* 1908, **26**, 985).—The instrument was designed for the investigation of the polarisation produced by reflection. The light was linearly polarised previous to incidence on the reflecting surface, and after reflection was received by a modified Babinet compensator. Emerging from this again linearly polarised, it was examined by a half shade analyser, which consisted of a nicol, capable of measurable rotation, and a smoked glass plate. It was claimed that for measurements of elliptically polarised light the instrument was more accurate than the ordinary Babinet compensator combined with an analysing nicol.

For such purposes as the measurement of the rotation of plane polarised light, the compensator could be removed and the half shade analyser used alone. J. R. C.

168. The Dispersion of Artificial Double Refraction. L. N. G. Filon (*Phil. Trans. Roy. Soc.*, 1907, *A*, **207**, 263).—When glass is compressed unequally in different directions it behaves like a crystal the optic axis of which is along the line of stress. If T_1, T_2 are the principal stresses in the wave front, μ_1, μ_2, the refractive indices for the two rays for which the directions of vibration are along T_1, T_2, then the relative retardation is $R=(\mu_1-\mu_2)\tau=C(T_1-T_2)\tau$, where τ is the thickness of the glass traversed, and C is the "stress-optical coefficient" of the glass. Wertheim found that C is independent of the wave-length of the light employed, but experiments by Pockels (Vol. II., Abs. Nos. 96, 182, and 264) and the author (Vol. II., Abs. No. 265) did not confirm this. The experiments described in this paper were undertaken to find how C varied with the light used. The method of investigation and the apparatus employed were fully described, and the various corrections discussed in the first half of the paper.

In the second half the experimental results were considered, and an empirical formula, $C=C_0/(1-\lambda_0/\lambda)$, C_0 and λ_0 being constants, was found to represent them. Theoretical considerations led to a formula of the type $C=\Sigma C_p/[1-(\lambda_p/\lambda)^2]$, where λ_p is the wave-length of light belonging to one of the free periods of the atoms of the glass. The results did not fit this so well.

The majority of the glasses were borosilicates made by Zeiss. The compositions are appended. Glasses 3453 and 3296 exhibited systematic deviations from the linear law. The deviations were local, and were probably due to an absorption band corresponding to a free period efficient in producing double refraction under stress. On the whole, it was found that B_2O_3 increased and K_2O decreased the coefficient C_0, λ_0 being unaffected by the chemical composition. The dispersion of double-refraction was thus roughly proportional to the stress optical-coefficient. For the glass 2783, Hooke's law was not valid, and it was found that the optical effect was proportional to the stress, and not to the molecular strain.

Table of Percentage Chemical Compositions.

Number of glass.	1809.	3453.	2783.	3296.	935.	3413.	3749.
SiO_2	35·4	68·1	52·7	67·5	32·5	31·6	70·2
PbO	18·7	—	31·6	—	28·2	23·6	—
Al_2O_3	3·7	—	0·6	—	8·5	8·0	—
ZnO	—	—	1·2	—	—	—	—
MgO	0·5	5·4	—	0·4	—	—	—
B_2O_3	34·3	5·7	1·4	15·4	27·7	33·0	5·9
K_2O	7·4	20·8	12·5	16·7	3·1	3·8	23·9

J. R. C.

169. A New Method of Measuring Directly the Double Refraction in Strained Glass. L. N. G. Filon (*Proc. Roy. Soc.*, 1907, *A*, **79**, 440).—The author showed, by simple analysis, that a rectangular glass slab, under flexure in a vertical plane perpendicular to the direction of the incident light, by which it was examined, deflected the wave front like a prism. It did so to a different extent, according as the ray was polarised in the plane perpendicular to the plane of flexure or in that plane. If, therefore, a beam of unpolarised light was analysed, after refraction, by means of a grating, the spectrum lines all appeared doubled. By measuring the shift of the spectrum lines, the stress-optical coefficients for the two directions of polarisation could be found, and hence the absolute changes in the indices of refraction could be calculated.

J. R. C.

170. The Polarisation of Light by Reflection from Glass. L. Zehnder (*Ann. Physik*, 1908, **26**, 998).—The instrument described in Abs. No. 167 was used to examine the polarisation of light reflected from glass surfaces. The glasses were all transparent, and it was found that ordinary unpolarised light, on reflection, became elliptically, not linearly, polarised, even when it was incident at the polarising angle. The component polarised perpendicular to the plane of incidence never vanished in the reflected beam, but had a minimum, very small, value for the principal angle of incidence. If the polarising angle was defined as that for which the component, polarised perpendicular to the plane of incidence, was least, then the principal angle of incidence and the polarising angle coincided. But this was not exactly the angle calculated from Brewster's law by means of the refractive index as determined by the method of minimum deviation, or any other method. For the six specimens examined the polarising angle experimentally ascertained was greater than the calculated angle by amounts varying up to one degree.

J. R. C.

VI.—Illumination and Illuminating Ware.

171. Preparation of Thorium Compounds. J. V. Clarke and W. A. Clarke (Brit. Pat. No. **120748**, September 21st, 1917, No. 13617).—The specification refers to the treatment of solutions containing thorium, obtained, for instance, by dissolving in water the product of the action of sulphuric acid on monazite sand.

H. G. C.

VII. Fuels, Refractories, and Furnaces.

172. The Standardisation of Tests for Refractory Materials. II. Provisional Specification (Committee of Ceramic Soc., *Trans. Cer. Soc.*, 1918, **18**, 251. Compare abstract of Part I, this Journal, 1918, **2**, A., 162).—*The Grading of Clays according to the Size of Grain.*—It is proposed to separate clay particles into groups, so that the sizes of the particles in each group range between certain specified limits determined by means of sieve analysis and elutriation.

Standard lawns established by the Institute of Mining and Metallurgy are suitable for the sieve analysis. The material should be slopped and the fine stuff washed through each lawn; the residue is then dried and weighed.

For the elutriation there are several forms of apparatus. A description and diagram are given of a convenient form to use with distilled water. Distilled water is recommended for comparison work owing to the fact that the salts dissolved in hard water tend to flocculate the clay particles.

Each elutriation should be standardised, so as to determine the volume, v, of outflow per sec.[*]

E. Schöne found empirically that if V represents the velocity of a stream of water in millimetres per sec., the maximum diameter, D, of spherical sand grains of specific gravity 2·65, which will just move with the stream can be represented by the expression

$$D = 0{\cdot}0314\,V^{0{\cdot}636} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

provided the velocity of the stream is between 0·1 and 12 mm. per sec.[†] It follows that when

Velocity = 0·166, 0·717, 1·460, 3·020 mm per sec.
Diameter = 0·010, 0·025, 0·040, 0·063 mm.

---

[*] This is equal to the number of millimetres of a given column of water which flows past a given point in a second multiplied by the sectional area.

[†] These are the limits usually employed in the analysis of clays.

When dealing with grains of specific gravity, S, appreciably different from 2·65, equation (1) becomes

$$D = 0{\cdot}0518 \frac{V^{0{\cdot}636}}{S-1} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

In order to obtain fractions with the limiting sizes suggested above, the corresponding velocities can be calculated from the expression:

$$V = 104{\cdot}7(S-1)^{1{\cdot}57}D^{1{\cdot}57} \quad . \; . \; . \; . \; . \; . \; . \quad (3)$$

These formulæ have been found to agree very closely with results obtained by actual measurement.

The following fractions have been in use for some years, and are recommended for grading finely-ground materials, fireclays, etc.

Proposed Fractions for Grading Fireclay, etc.

Maximum velocity mm. per sec.	Extreme diameters mm.	Average diameters mm.
0·18	Below 0·01	0·0063
0·30 (200's lawn)	0·01 to 0·063	0·042
Residue (120's lawn)	0·063 to 0·107	0·087

The advantage of this classification is that two of the three fractions can be separated by sieves and only one fraction is left for the elutriation.

It is often difficult to compare the fineness of two or more clays, even when knowing the fractions. For example, if a powder has the three fractions 45, 10, 45 per cent. and another the fractions 35, 25, 40 per cent., the question arises as to which is the finer powder. One method of classification employs what is called the *surface factor.*

In this system the surface area of the particles, assumed to be spherical, in each group is computed, and the surface area of the particles in all the groups added together make the so-called surface factor.*

Let W_1, W_2, and W_3 denote the respective weights of the fractions, W_1 being the finest, of unit weight of powder, and d_1, d_2, d_3 the corresponding average diameter of the grains in the fractions. The surface factor then reduces to

$$SF = 359W_1 + 53{\cdot}9W_2 + 26{\cdot}0W_3.$$

The clay having the smaller surface factor is the finer one of the two.

Sifting as an absolutely trustworthy guide is open to objection since spherical particles are never obtained, whilst fine sieves introduce difficulties as they hold particles in their meshes. Elutriation appears to give a more trustworthy classification.

It is suggested that speeds should be standardised in terms of water levels and nozzle apertures only. The grading limits of 0·01 and 0·05 mm. were suggested as convenient. A recommendation was also made that sand, silt, and mud should be differentiated as three big groups, with grain size:

---

* The principles are discussed in *Trans. Cer. Soc.*, 1910, **9**, 94.

Sand	1 mm. to 0 1 mm.
Silt	0·1 mm. to 0·01 mm.
Mud	<0·01 mm.

Each of these could be subdivided into three fractions as indicated above.

The Corrosive Action of Flue Dusts on Refractories.—A furnace in which town's gas and compressed air were used was designed and used for observing qualitatively the effect of flue dusts on refractories. The dust-feeding device consisted of a hopper with an internal cone, screw controlled by a small hand-wheel. The lifting of the cone allowed the dust to pass through a glass tube into the burner, where it became mixed with the incoming air and gas.

Bricks were placed centrally in the bottom of the firing chamber, heated slowly up to the maximum temperature, which was maintained for half an hour; a steady stream of dust was then allowed to pass into the burner and the furnace conditions kept constant for a period of thirty minutes, after the whole of the dust had been used.

The points requiring attention were:—

(1) The distance the brick was placed from the burner.

(2) The rate of heating.

(3) The maximum temperature reached.

(4) The nature of the flame (oxidising or reducing).

(5) The time the brick was exposed to the maximum temperature before the dust was allowed to enter.

(6) The amount and grain-size of the dust, and rate at which it was fed on to the brick.

(7) The space between the brick. There was a tendency for dust to penetrate from the side.

(8) The time the brick was kept heated after the dust had all been used. A. M. J.

173. The Apparent Causes of Failure of Lead Glass-pots. A. F. Gorton (*J. Amer. Cer. Soc.*, 1918, **1**, 648).—The author ascribes the strains set up in a glass-house pot during its working existence as due to (1) irregular heating in the pot arch, caused by uneven distribution of the heat; (2) mechanical strain set up during transference of the pot from the pot arch to the furnace; (3) sudden chilling on the introduction of cold (sometimes damp) batch; (4) the erosion of the clay due to the ebullition of the metal during the found; and (5) the hydrostatic pressure of the glass, which was sometimes sufficient to cause the pot walls to bulge. There were also chemical actions giving rise to weakness in the pot, such as the corrosion of the clay by the glass and the slagging action due to iron.

It was frequently very difficult to decide the exact cause of any particular pot failure, but the general defects were as follows: (1) Pitting and corrosion of the bottom usually resulting in a leak.

This was particularly marked at the junction of the bottom and side walls; (2) cracking of the bottom; no corrosion except in the crack; (3) cracking in the sides, the cracks extending through the walls and causing leakage of the pot contents; (4) holes in the sides, usually a foot or more above the bottom; (5) furrows in the side-walls, from the metal line downwards; (6) bulging of the pot sides; (7) holes through the back of the pot; (8) vertical cracks through the back of the pot; (9) cracking under the hood; (10) cracking or caving in of the crown.

From a study of the collapse of 379 pots the author found that 81 per cent. broke in the bottom, 11 per cent. in the side, and 6 per cent. in the back. Most of the bottom failures were due to cracks, and as the pots had a comparatively short life, the cracks were probably caused (1) during drying, (2) during arching, or (3) in setting. When cracks open in drying they were always from side to side. The majority of cracks ran from front to back, and in one case corresponded exactly to the situation of the prongs of the fork during the pot setting.

Corrosion was apparent in many cases, and in a great majority of instances the presence of iron was detected. In some cases the author found metallic lead at the bottom of cracks and hollows, embedded in a mass of slagged clay, from which he concluded that metallic iron reduced the lead silicate, forming ferrous silicate and metallic lead.

Iron might have an effect due to entering from the batch or from the material of the pot itself. To prevent the accidental presence of metallic iron in the batch the author recommended magnetic separation and screening just before the batch was introduced into the pot, as he regarded the corrosion as due principally to metallic iron in the batch. When iron was not the cause of the trouble, the corrosion might be due to the convection currents set up in the molten glass, which rose up the sides of the pot and tore away small portions of the clay from the sides of small crevices caused by the chilling action of the cold batch. The corrosion took place much more extensively in the more porous parts of the pot, particularly the bottom, whereas the vitrified dense portions were not acted upon to anything like the same extent.

Holes in the sides of the pot might be caused by the glass attacking a surface particle of pyrite, and then, when the more resistant surface layer had been penetrated, continuing the attack on the more porous material beneath.

Deformation of the pot was caused chiefly by the use of a pot clay not sufficiently refractory for the temperature and conditions under which it was employed, and might result directly from (1) failure to take down the stopper at the correct period of the fining process; (2) "forcing" a pot; or (3) excessive heating due to uneven distribution of heat in the furnace.

The bottom of the pot was always more porous, and therefore more liable to attack and corrosion than the sides. Lining the pot with an aluminous or porcelain-like material was unsatisfactory, owing to the danger of the lining cracking and exposing the porous clay below. The only safe method was to burn the pot thoroughly at a temperature of about 1400°, the heat being applied directly to the bottom of the pot.

The author concluded that it was highly desirable search should be made for a material superior to fireclay both in regard to its refractoriness and resistance to corrosion. J. H. D.

174. Method for Determination of the Air in Plastic Clay. H. SPURRIER (*J. Amer. Cer. Soc.*, 1918, **1**, 710).—After studying the manner in which plastic clay disintegrates under the action of boiling water the author concluded that the disruption was due to the expansion and subsequent escape of the contained gas vesicles. Clay prepared by different methods, for example, by throwing, filter pressing, or extrusion, showed distinctive disintegration on treatment with boiling water.

The method adopted for determining the amount of air contained in a sample of pugged clay was as follows: The measured (or weighed) sample of clay was placed in a strong 600 c.c. flask fitted with a two-holed rubber stopper. In one hole was fitted a gas collecting tube so arranged that suction could be applied by means of a vacuum pump. Through the other hole a piece of glass tubing was passed which could be connected at will with reservoirs of kerosene or boiling water. The apparatus was filled completely with kerosene, which was then displaced by boiling water by means of the pump. The boiling water disintegrated the clay, and the gases released were collected and measured in the gas-collecting tube.

A sample of air-free clay after being passed through a pug mill was found to contain 9·61 per cent. by volume of air. On passing this clay through another pug mill with well-set blades, the air-content was found to be 9·88 per cent., and on passing another sample five times through a special pug mill the air content was found to be 13·18 per cent.

The method was adapted for use in ascertaining the proper blade setting of pug mills and the soundness of pugged clay so far as the air-content is concerned. J. H. D.

175. Notes on Sagger Clays and Mixtures. G. H. BROWN (*J. Amer. Cer. Soc.*, 1918, **1**, 10, 716).—The author points out that the requisite properties of saggars are (1) refractoriness, (2) mechanical strength, (3) resistance to deformation, and (4) resistance to chemical changes.

Porosity and shrinkage curves are given showing the behaviour of four typical clays under heat treatment. Type (1), a vitreous bond clay, showed high shrinkage and low porosity at 1150°. At about 1250° the shrinkage attained a maximum and the porosity a minimum, both remaining practically constant for further temperature increases; type (2), a refractory open-burning clay with high porosity and low shrinkage at 1150°, both becoming constant at 1300°; type (3), a clay with high porosity and low shrinkage at

1150°; the porosity decreasing and the shrinkage increasing steadily with increasing temperature, but equilibrium not attained until a very high temperature was reached; type (4), the shrinkage increasing and porosity decreasing up to a temperature of 1275°. On further heating, the shrinkage decreased and porosity increased rapidly, showing the development of a vesicular structure.

Type (1) was suitable for a bond clay and type (2) for a base clay, but types 3 and 4 were unsuitable for saggar making.

The mechanical strength of the burnt clay depended upon (1) the extent to which the bond clay vitrified at the finishing temperature of the kiln, (2) the size and grading and the proportion of grog, and (3) the presence or absence of hair cracks produced during drying and firing. The greater the amount of bond clay in the mixture the greater its mechanical strength, but the smaller its power of resisting temperature changes. By varying the proportions of bind clay, base clay, and grog, saggars of any desired mechanical strength could be produced. The author suggested as a good mixture the following proportions: Bind clay (vitrifying clay), 20; base clay (open burning clay), 30; and grog, 50 parts.

The causes of hair cracks were either (1) grog of too large a size or of improper grading, or (2) the use of a bond clay which had too great a drying and firing shrinkage.

Deformation of the clay at high temperatures could usually be corrected by the substitution of some or all of the vitrifying bond clay by open burning refractory clay.

To obtain resistance to temperature changes the structure of the saggar should be as open and porous as possible, consistent with sufficient mechanical strength in the cold. The presence of free quartz should be avoided as far as possible.

The author favoured the mixing of the saggar clay by the wet-pan process, and claimed that this produced a more intimate mixture than soaking and mixing by hand. To obviate crushing the grog during the mixing process, the rolls should be raised slightly from the bottom of the pan. J. H. D.

176. The Corrosive Action of Flue Dust on Firebricks. J. W. MELLOR and W. EMERY (*Trans. Cer. Soc.*, 1918, **18**, 230).—The furnace used was that described in abstract No. 172. The following types of dust were investigated:—

(1) Boiler flue-dust of a slate-brown colour.

(2) Boiler flue-dust of a brown colour.

(3) Deep red-coloured dust from the top of the retort bench of a gas works.

(4) Dust from slag chamber between steel smelting furnace and regenerator.

(5) Dust from blast furnace Cowper stove.

(6) Bull dog.

(7) Red hæmatite ore.

(8) Tap cinder.

(9) Lime from calcined marble.

(10) Lime and common salt, in equal proportions.
(11) Salt.
(12) Sodium sulphate.
(13) Salt and potash spar, in equal proportions.
(14) Sodium silicate and calcium silicate in equal proportions.

The chemical composition of the dusts was stated. Only the fraction passing a 60 lawn mesh was used. At temperatures below 1300° the action of the dust was mechanical rather than chemical. Each dust had its own critical temperature, but in this survey the temperature was kept at 1400°. Five types of firebricks were used with each dust. Analyses of these are given and also a description of the texture.

A description was given of the extent of attack of each dust on each type of brick.

It was not possible to express the results of the corrosive action of flue-dusts in a quantitative manner by weight, by measurement, or by graphic diagram. Photographs of the firebricks after attack did not express the extent of attack, nor was sufficient reliance to be placed on the depth of penetration of attack to enable it to be offered as a quantitative test.

The following table attempts to summarise the results:—

Dust.	Firebrick.	Silica brick.	Fine-grained Silica-brick.
Boilerdust high in lime and ferric oxide	d.P. ; m.C.	—	—
Ferruginous boiler dust	s.P. ; s.C.	—	—
Ochreous dust from retort brick	k.P. ; s.C.	d.P ; g.C.	—
Basic slag	d.P. ; s.C.	d.P. ; m.C	—
Ferruginous dust high in lime	k.P. ; m.C.	d.P. ; m.C.	—
Bull dog	—	d.P. ; s.C.	—
Hæmatite (reducing flame)	—	d.P. ; s.C.	s.P. ; s.C.
Tap cinder	d.P. ; m.C.	d.P. ; m.C.	d.P. ; s.C.
Lime	s.P. ; m.C.	s.P. ; m.C.	—
Lime and salt	s.P. ; m.C.	s.P. ; m.C.	—
Salt	d.P. ; s.C.	s.P. ; m.C.	—
Sodium sulphate	s.P. ; s.C.	s.P. ; m.C.	—
Salt and felspar	s.P. ; s.C.	s.P. ; m.C.	—
Soda-lime glass	s.P ; s.C.	s.P. ; m.C.	—

P = penetration ; C = corrosion ; s = slight ; d = deep ; k = complete
m = medium.
g.C. = great corrosion or slagging.

It was possible that the test on a refractory could be best carried out by moulding mixtures of the dust and the ground refractory in definite proportions in the form of cones and determining the fusing point.*

In general, the penetration of the dust was greater in fireclay than in silica bricks. In most cases the bond was attacked first and the coarser grains last. In silica bricks the depth of penetration by the dust was generally less the finer the grain. The bond of a silica firebrick offered the feeblest resistance to the attack of a corrosive, slag. Under oxidising conditions iron oxide did not corrode silica bricks to any noteworthy extent, but under reducing conditions ferrous silicate acted as a corrosive flux. As a rule, iron oxides corroded fireclay bricks more than silica bricks.

---

* *Trans. Cer. Soc.*, 1913, **13**, 12.

The dusts apparently exerted an influence on the conversion of the quartz into the low specific gravity form or forms even when the coarse grains have apparently not been penetrated.

When the dust was such that it could form a surface glaze the brick was protected from further attack, or, rather, the subsequent rate of attack was considerably diminished. Attempts to give a brick a resistant face by fusing the surface by means of a blow-pipe flame were not satisfactory because the surface skin peeled off.

A. M. J.

177. Some Notes on Silica and other Refractory Bricks made from Non-Plastic Materials. G. W. Mottram (*Trans Cer. Soc.*, 1918, **18**, 148).—The author was led to the conclusion that in the making of refractory bricks there was a marked shortage of very fine material employed. Bricks were therefore made containing 90 per cent. of grog and 10 per cent. of fireclay by grinding the raw clay to a fine slip with two or three times its weight of grog and afterwards mixing the resulting mixture with the remainder of the ground grog. Bricks made on this principle from calcined Stourbridge fireclay showed no contraction after repeated burning, and, after a week's exposure in the port of an open-hearth steel furnace came out with the edges quite sharp.

The method is stated to be specially applicable to the grinding and preparation of materials for silica bricks. By grinding 15 to 30 per cent. of the material with lime, clay, or other binder to a fine slip and then adding this mixture to the remainder of the graded silica material there is not only the necessary fine material assured to fill in the voids and act almost as a cementing medium, but the binder is brought into intimate contact with every particle of the silica. Up to 95 per cent. of grog can be used. The degree of porosity of the resulting product depends upon the fineness and treatment of the mixture.

The author referred to the fact that Le Chatelier had been working on similar lines as regards the introduction of very fine grinding into the preparation of the mixture for silica bricks, and the following conclusions had been drawn on tests of such bricks carried out in a French works.

1. With "all fine" material the crushing strength reached 4,540 lb. per sq. in.

2. With "coarse" grains passing 100-mesh, and retained on 120-mesh, 993 lb. per sq. in.

3. With "fine" + graded grains up to $\frac{1}{3}$ in. the average was 3,095 lb. per sq. in.

All these bricks were burned at 1300°. The durability of bricks made on this system—in the same works—from similar material, and used under similar conditions, was some 200 to 300 per cent. in excess of bricks made with the usual method of grinding, and up to the time of publication they were giving every satisfaction.

When "all fine" grinding was used the permanent expansion could be eliminated, but in the graded mixture which was preferred, it amounted to 1·6 per cent.

The author stated that the graded mixture, containing large particles, as used in the ordinary method of making, gave the best results. The fine material produced a stronger article. In silica bricks this fine material was more rapidly converted than the larger particles. Fifteen per cent. of the very fine was a decided advance on the present practice, but 25 per cent. and sometimes more was preferable.

The extra cost of grinding, with a properly arranged plant, was not a serious matter, as was evident by the price at which Portland cement (180 to 200 mesh) could be sold in normal times.

The author also pointed out that where calcination was desirable (for magnesite and some silica rocks) it would be more effectively done, and at much less cost than in shaft or chamber kilns, by reducing the rock to a powder and passing it through a rotary kiln. He suggested further that the burning of bricks, particularly the question of up- *versus* down-draught kilns, was deserving of close attention. A. M. J.

178. Study of Silica Products. Part II. Bricks. A. Bigot (*Trans. Cer. Soc.*, 1918, **18**, 165; compare this Journal, 1918, Abs. 168).—In the present paper the author dealt only with silica products used in the Martin or similar furnaces.

The products were tested analytically, physically, and micrographically, (*a*) on products dispatched from factories, (*b*) on the same products submitted to the temperature 1710° for an hour or two or to 1650° for the time necessary for their complete expansion.

In (*a*), the physical tests included determinations of density, porosity, and resistance to crushing. It was concluded that if the burning had been high enough and long enough the absolute density of silica products should be below 2·40 for materials made from quartzites and below 2·25 for materials made from compact flint.

In regard to porosity, certain bricks had a value of 8 per cent., others higher porosities, sometimes reaching 20 per cent. If of good quality the porosity should decrease when the products were heated to 1710°.

The resistance to crushing at ordinary temperature was measured by the process adopted by the Conservatoire National des Arts et Métiers. According to the physical properties of the products, the resistance to crushing at ordinary temperature varied from 120 to 500 kilog. per sq. cm.

In tests (*b*) the burning of the bricks to 1710° was performed in Bigot and Bodin's recuperative furnace. After the burning the expansion, density, porosity, and resistance to crushing when cold and at 1500° were determined. Pieces which on burning to 1710° had either softened and deformed or had melted were of inferior quality and not suitable for use in a Martin furnace. Where they had resisted without either melting or being deformed, three principal cases occur:

(1) With increase of temperature the siliceous grains increased in volume and porosity; the cement which surrounded them was partially vitrified, contracted, and resisted (without cracking) the expansion of the silica grains. The porosity of these products decreased in proportion as they were heated to higher temperatures. The best silica products presented this peculiarity.

(2) The grains expanded too much and broke the enwrapping cement; the porosity of the product consequently increased. Such products became friable, less resistant to crushing, and were more easily attacked by the dusts and slags of furnaces.

A manufacturer wishing to use a rock the increase of volume of which was considerable should grind it finely and avoid the use of all large grains.

(3) The grains themselves fall to powder, whilst the enwrapping cement preserved its consistency and did not crack. Here, again, the porosity would have increased, the resistance to crushing at ordinary temperature decreased, and the resistance to crushing at 1500° become zero.

The author describes the results of experiments made with silica bricks taken from the arches of Martin furnaces at Creusot. Each brick showed three very distinct zones, D, E, F, D being unattacked silica brick in contact with atmosphere; E, brown in colour and containing silica grains analogous to those in D, their size decreasing as the part F was approached; F, grey, and no longer containing grains visible to the naked eye.

The following represented the mean values for a series of analyses:

	Silica.	Lime.	Magnesia.	Iron oxide.	Alumina.	Manganese oxide.
Grey part ...	84·60	3·55	1·05	9·25	0·60	0·95
Brown part ...	78·45	4·95	1·15	13·10	1·20	1·15

The iron in the grey part was in the ferrous state (even though the working conditions of the furnace were not, in general, reducing). In the brown part it was partially ferric; about half was attracted by a magnet. Cones made of the three materials all remained intact when heated up to 1690°; about 1710° the brown part (E) melted and liquefied abruptly; whilst about 1730° D and F became pasty without actually melting.

The author's experiments lead him to conclude that:

(1) Contrary to the usual view that silica products are only of good quality if they contain 94—95 per cent. silica, the grey parts of the bricks which contain only 85 per cent. silica are as refractory as products with 95 per cent. silica, and far superior as regards crushing resistance at all temperatures.

(2) An excess (over 3—4 per cent.) of lime and iron oxide is not necessarily detrimental in silica products.

(3) Refractory products can be classified as (*a*) those of which the crushing resistance presents a maximum at about 1,000°; (*b*) those which do not present a maximum. In the first category occur kaolins, clays, bauxites, silica products, and products with carborundum as basis. In the second category should be placed products of chromite and magnesia.

The author suggests that the occurrence of a maximum crushing strength may be connected with the decrease in the coefficient of expansion which some refractories show in the neighbourhood of 1000°. A. M. J.

179. Magnesia Ware. T. D. Yensen (*J. Amer. Cer. Soc.*, 1918, **1**, 730).—The author's process was as follows: Calcined magnesite was fused in the electric arc, and the resulting fused magnesia crushed through a 40-mesh screen. The product was mixed with 5 per cent. of hydrated magnesia and moulded into crucibles in a steel mould. The crucibles were afterwards dried and finally heated to 1800° in an electric furnace. The crucibles were strong and uniform, had little shrinkage, and showed no sign of softening at 1800°. The finished product contained 95 MgO, the remainder being chiefly SiO_2, Al_2O_3, and Fe_2O_3. A purer and more highly refractory product could be obtained by using a purer raw material.
J. H. D.

180. Notes on Certain Characteristics of Porcelain. A. V. Bleininger (*J. Amer. Cer. Soc.*, 1918, **1**, 697).—The physical properties of porcelains, such as thermal expansion, heat conductivity, and electrical resistance, vary widely at different temperatures. This variation is due to variation in the stage of development of equilibrium conditions in the porcelain. The attainment of equilibrium depends upon the composition, fineness of grinding, intimacy of mixing, rate and temperature of firing, and the rate of cooling, so that as a result the amounts of undissolved silica, of glassy matrix, of undecomposed clay, and of *sillimanite* vary within wide limits in any particular porcelain. In low-fired porcelains (fired to about SK.10) the amount of undissolved *quartz* is large and of *sillimanite* small, and therefore it would be expected that this type would show changes in specific volume on heating corresponding with the *quartz-cristobalite* inversions. It would also be expected that with the employment of higher firing temperatures, causing more complete solution of the quartz and formation of *sillimanite* from the clay substance, the porcelain structure would become more homogeneous and therefore more balanced. The development of *sillimanite* is held to be desirable on account of its stability, density, low thermal expansion, and its not being subject to transformation changes.

Porcelains of excellent stability, as shown by the resistance of the bodies to sudden heating and cooling, have been obtained, in which the quartz has been replaced both by clay and by synthetic *silli-*

manite (prepared by heating a mixture of 258 parts of kaolin, 102 parts of calcined alumina, and 7·2 parts of boric acid to SK.20 and grinding the product). The porcelain obtained from a mixture of 40 parts of the *sillimanite* calcine, 40 parts of clay, and 20 parts of flux showed excellent resistant properties as regards sudden heating and cooling, and also high mechanical strength. Similar results were obtained by the use of other minerals not subject to molecular transformations, such as fused alumina and zirconium oxide.

It was found that the higher the felspar content in porcelain the lower was the electrical resistance. By eliminating the felspar and increasing the maturing temperature of the porcelain to SK.18—20 bodies of good resistance were obtained. Replacing the felspar by synthetic silicates containing beryllium oxide, magnesia, etc., had a similar result in improving the resistance of the porcelain. With high felspar content polarisation phenomena become evident, indicating that the felspar acts as an electrolyte. J. H. D.

181. Zirconia and its Uses. A. GRANGER (*Moniteur. Scientifique*, 1919, p. 5).—Among the chief zirconia-containing minerals mentioned by the author are those recently discovered in Brazil, *zirkite* and *baddeleyite*. The working up of various minerals which are compounds of zirconia and other oxides with silica, can be effected with the aid of hydrofluoric or sulphuric acid, by fusion with alkalies, or by transforming the zirconia into a carbide. An often troublesome impurity is iron oxide, which can only partly be extracted by acids, and which stands in the way of the much-attempted utilisation of zirconia for rendering glasses and enamels opaque. The minerals and zirconia itself are not very satisfactory as abrasives because a suitable binder is difficult to find. This is also the main trouble in the use of zirconia as a refractory material, for which it is held to be otherwise excellently suited. Crucibles and tubes for electrical resistance heating have been made from zircon, using calcium oxide, sodium silicate, organic compounds, and clay as binders. The crucibles were satisfactory, but the resistance tubes were soon destroyed by arcing. Zirconia bricks with tar as binder have proved very satisfactory and economical when used for lining open hearth steel furnaces; such bricks, however, are attacked by fluorides and acid sulphates. S. E.

182. Zirconia: Its Occurrence and Application. H. C. MEYER (*Trans. Cer. Soc.*, 1918, **18**, 264).—The word "zirkite" was used by the author to designate any commercial ore of zirconium such as that furnished by the deposits near Caldas, Brazil. This was essentially a mixture of *brazilite*, *zircon*, and a new and unnamed zirconium silicate.

The zirkite could be roughly divided into two classes: (1) Alluvial pebbles ranging in size from ½ in. to 3 in. in diameter and carrying about 90 to 93 per cent. of zirconium oxide. These pebbles, known as "favas" and having a specific gravity ranging from 4·8 to 5·2, were found along small stream beds and on the talus slopes of low ridges. (2) Zirconia ore proper, which ranged in shade from a light grey to a blue-black. The lighter coloured material carried a higher percentage of zirconium silicate; the blue-black ore contained from 80 to 85 per cent. ZrO_2. This ore had the same crystalline form as zircon (67 per cent. ZrO_2), but it was readily soluble in hydrofluoric acid, whilst zircon was not affected.

No extensive development had yet been attempted; most of the mines were many miles from the railroad, and primitive carts requiring eight to sixteen oxen had to be used for transport over the mountainous roads. To indicate the variation in the character of zirkite, six representative analyses were given:—

	1.	2.	3.	4.	5.	6.
ZrO_2 ……………	93·18	81·75	86·57	85·93	82·00	71·88
SiO_2………………	1·94	15·49	2·50	9·35	11·38	25·31
TiO_2 ……………	0·69	0·50	1·43	1·84	0·36	0·63
Fe_2O_3 ……………	2·76	1·06	5·29	1·93	2·08	0·43
Al_2O_3 ……………	0·64	0·85	1·00	0·36	0·62	0·15
MnO ……………	trace	trace	—	—	—	—
H_2O………………	0·47	0·63	3·32	1·56	3·35	1·56
	99·68	100·28	100·11	100·97	99·79	99·96

The other important ore of zirconia was the silicate known mineralogically as *zircon*. Unlike zirkite, there were several important deposits of this type of zirconia ore in various parts of the world, namely, N. Carolina, Florida (U.S.A.), S. Norway, and Brazil. In the case of the Florida and Brazil deposits the *zircon* was secured as a by-product in the electro-magnetic concentration of monazite sand.

Zircon sand consisted of minute, glassy crystals and had very much the appearance of a fine, white sea sand.

A theoretically pure *zircon* only carried 67 per cent. of ZrO_2; an average *zircon* sand carried about 64 per cent. of ZrO_2, whereas even the low grades of zirkite carried a minimum of 70 per cent. of ZrO_2. This low oxide content coupled with the fact that *zircon* was not so amenable to chemical treatment as zirkite made an extensive demand for *zircon* doubtful.

The high melting point, low coefficient of expansion, and low thermal conductivity caused zirkite to rank as a refractory of the first order. Zirkite itself had little or no plasticity, and the selection of the proper binder governed the melting point and fire-shrinkage of zirkite brick. Briquettes had been made to test various binders, electrically dead-burnt magnesia and water-ground zirkite having given the best results.

The cost of electrically dead-burnt magnesia was so heavy that it was often replaced by ordinary calcined magnesia, although it had an extremely high shrinkage.

The following formulæ were used in the making of briquettes which were carefully dried and burnt at a temperature of 1427° approximately:

Formula 3A.

45 grams of zirkite (ground to pass 80-mesh screen).
45 grams of magnesium oxide (calcined).
10 grams of water-ground zirkite.

Formula 3B.

72 grams of zirkite (ground to pass 80-mesh screen).
18 grams of magnesium oxide (calcined).
10 grams of water-ground zirkite.

The briquettes made from the two formulæ had much the same appearance—a brownish-yellow cast, a rather loose texture, but quite resistant to abrasion, and of a fair tensile strength. The fire shrinkage in each case was approximately 8 per cent. linear measurement. One of the briquettes at a white heat was dropped into a beaker of water, but no cracks were developed and the material was apparently as solid as before quenching.

Some standard-sized firebricks were also made, using zirkite ground to pass an 80-mesh screen and 5 per cent. clay. The mass was slightly moistened and formed into bricks in the same manner as was pursued in the manufacture of silica or chrome bricks. After thorough drying, the bricks were burnt in a silica brick kiln at an estimated temperature of at least 1649°. Such bricks were tested in various ways. A temperature of 1800° appeared to be the upper limit at which such bricks could be safely used; for while the bricks did not fuse or flow under their own weight at that temperature, they were readily affected by pressure. Used in a furnace up to 1800°, the bricks would have been deformed.

Whilst not entirely free from shrinking and cracking, these bricks were better in this respect than magnesite bricks, although not so good as carborundum. Their heat conductivity was apparently less than that of other high refractories.

After heating to 1800° in contact with the carbon of a resistance furnace the surface of the bricks was slightly pitted and spongy, but the effect is not so bad and can probably be controlled.

A satisfactory commercial process has now been perfected for the manufacture of zirkite brick in the U.S.A.

Metallic Zirconium.—This has been produced in small quantities by Dr. C. James, of New Hampshire College, U.S.A. It is in the form of a greyish-black, amorphous powder, which gives a powerful evolution of hydrogen when treated with hydrofluoric acid. When shaken near a flame the metal produces brilliant sparks, and small quantities can be readily ignited with a match. There are two other forms of metallic zirconium, namely, the crystalline and the graphitic types. The crystalline form has a density 6·4 and a melting point 1500°.

Summary of the Commercial Uses of Zirconium.

A. 1. The metal alloyed with iron is now finding application in the steel industry as a hardening agent.

2. As a scavenger for removing nitrogen and oxides from steel.

3. For the manufacture of drawn filaments for incandescent lamps. (Such filaments are claimed to have the property of selective radiation; in other words, emit more light than corresponds with the temperature to which they are heated by the electric current.)

4. To alloy with nickel for the production of high-speed cutting tools.

B. 1. The carbide is employed as a filament for incandescent lamps.

2. As an abrasive.

C. 1. The oxide is employed as a refractory body either in its pure form or in the semi-purified state known as zirkite.

2. In the manufacture of zirkite bricks.

3. In the manufacture of small, highly refractory utensils for laboratory purposes.

4. Combined with yttrium earth oxides for the manufacture of Nernst glowers.

5. As a substitute for calcium oxide in "lime" light cylinders and in the manufacture of pencils for the Blériot automobile headlight.

6. As an acid-proof enamel.

7. As a substitute for bismuth salts in making *X*-ray photographs.

8. As an addition to fused silica ware for the prevention of devitrification.

D. 1. The nitrate has been employed as a food preservative.

2. In the "lighting" fluids used in the manufacture of incandescent mantles.

E. 1. The basic acetate is employed for weighting silks.

A. M. J.

183. Refractory Compositions. G. Marsh (Brit. Pat. No. **120471**, December 3rd, 1917, No. 17893).—Ground furnace slag, slate waste, infusorial earths, and similar materials in admixture with Portland, Roman, or hydraulic cement, and, if desired, plumbago, are mixed with a solution of a proteid substance such as casein, blood, glue, gelatin. The solution may contain also sodium or potassium silicate, with or without addition of borax, boric acid, or ammonia. The mixture, when dried, is intended for use as a refractory material. Slate dust, slate waste, marble, granite, or similar material, mixed with Portland, Roman, or hydraulic cement, is mixed also with a similar solution to form artificial slate.

H. G. C.

184. A New Type of Recuperative Furnace. W. Rosenhain and E. A. Coad-Pryor (*Engineering*, 1919, **107**, 702).—In this paper, read before the Ceramic Society, the authors describe a new type of experimental furnace suitable for glass melting and for the firing and testing of refractories requiring very high temperatures for a considerable time. Since it was regarded as essential that a "night-shift" should be avoided, furnaces with air-blast from fan or blower and furnaces of the regenerative type were ruled out at once, whilst existing types of recuperative furnaces did not appear to be adaptable for use in small sizes, owing to the relatively large dimensions of the recuperator blocks and the thickness of the walls of the passages through which the interchange of heat takes place. The authors therefore designed a furnace with a natural draught which they state is not only eminently successful and satisfactory for their special purpose, but appears adaptable both to much larger and to smaller sizes.

Coal gas was the fuel used, and the authors considered that the principal factor must lie in the design and construction of the recuperator, and this in turn determined the entire design of the furnace. The only form of recuperator which gave promise of affording the desired efficiency appeared to consist of a nest or battery of tubes through which the incoming air is drawn, while the products of combustion circulate about the interior of the tubes. Sets of tubes made of vitreous silica, of the best fireclay, and of "salamander," rapidly failed in succession either by breakage or "sagging." Tubes made of a mixture of carborundum and China clay or good fireclay, proved eminently satisfactory. The composition of the tubes used varied somewhat, a larger percentage of clay being permissible in those tubes intended for use in the cooler parts of the recuperator. For the hottest parts, reaching a temperature of between 1400° and 1500°, a mixture of about 20 per cent. of China clay and 80 per cent. of silicon carbide was found quite satisfactory, although successful tubes were made with China clay up to 40 per cent. Care must, however, be taken to see that the China clay is of the most refractory type, and not contaminated with foreign fluxes. The tubes were fired up to a temperature of fully 1500°, a temperature higher than that at which they were

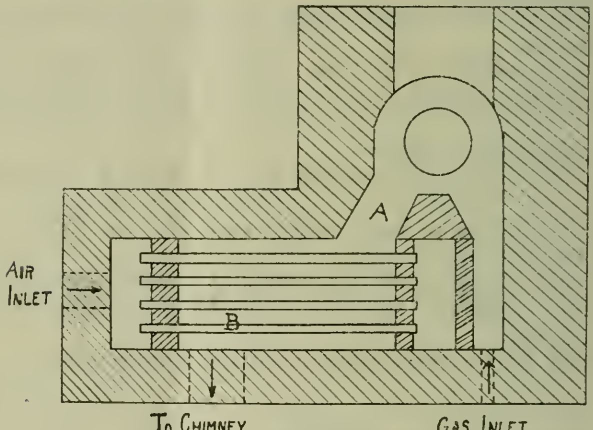


FIG. 48

to be used. This is important, since carborundum articles exhibit a great tendency to deformity the first time they are raised to a given temperature. During the firing they must, therefore, be carefully supported, and must not be used at a higher temperature than that to which they have been initially fired.

In the first furnace designed for glass-melting experiments, the combustion space was approximately cylindrical with a diameter of 24 in., and a height of 18 in., with a total volume of 4·8 cu. ft. and an internal surface of 16 sq. ft. The general arrangement of this furnace is indicated in the diagram Fig. 48, which shows a horizontal section. The recuperator contained fourteen tubes each 4 ft. long and $1\frac{1}{8}$ in. in diameter. The products of combustion took an uninterrupted course direct from the combustion chamber to the outlet flue, from *A* to *B* in the horizontal section, Fig. 48. The incoming air was not sufficiently heated, and there was undue heating in the chimney. The arrangement was, therefore, modified (Fig. 49). The number of tubes was increased to twenty and the recuperator lengthened by 13 in., the diameter of the tubes remaining the same as before. The course of the products of combustion through the recuperator were, however, controlled by four baffles, which caused the gases to follow a zig-zag and, consequently, much longer path from the combustion chamber to the outlet flue. This type of furnace gave very satisfactory service, temperatures of 1550° being obtained with ease in the melting chamber, whilst adjustment and control were easily achieved. From Fig. 49 it will be seen that pre-heated air leaving the tubes passes into a collecting chamber (*c*). and is then directed by a series of baffles (*D*) into a mixing chamber (*E*). Here it meets the coal gas, which enters by three horizontal tubes or burners (*F*); the flame is developed in chamber (*E*) and in the space around the pot in the combustion chamber, and passes out through the exit (*G*) into the recuperator. This particular furnace was provided with an opening at the front, through which the pots could be inserted or removed, and a working opening in the roof for manipulating the glass or other contents of the pot. In the subsequent development of the furnace the recuperator tubes

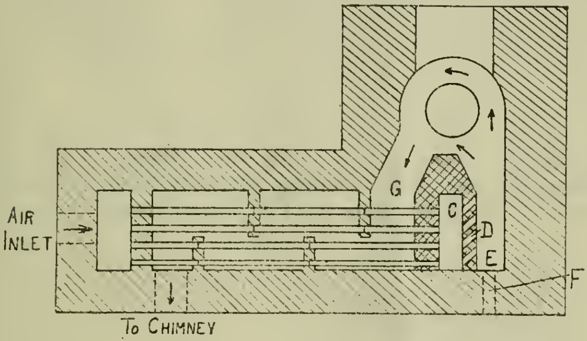


FIG. 49.

are much more numerous, thinner, and of smaller diameter, whilst the system of baffles was used more extensively.

Figs. 50 and 51 illustrate in horizontal and vertical section a furnace for the experimental firing and testing of refractories at high temperatures. The working chamber of this furnace has a floor area of 2 ft. 9 in. wide by 1 ft. 6 in. deep, having an arched roof with a minimum of 20 in., thus giving a total volume of 10 cu. ft. The flame passes horizontally across this space and a very uniform heat is produced, the variation from the inlet end to the exit end being of the order of 20° at temperatures in the neigh-

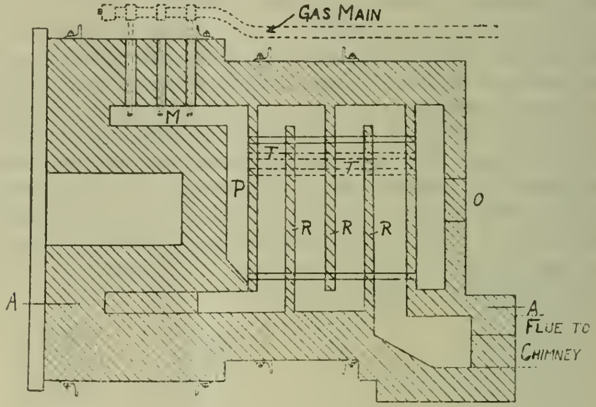


Fig. 50.

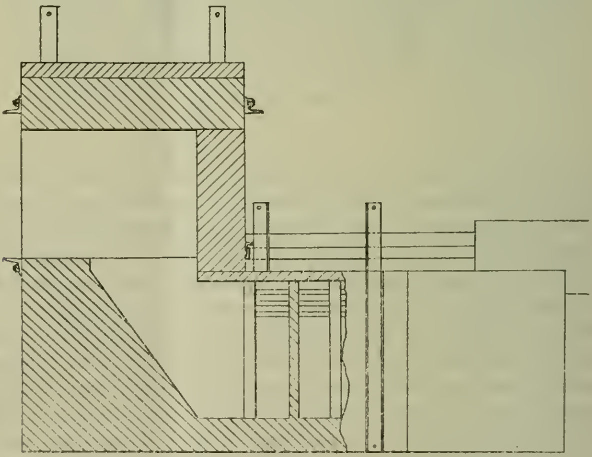


Fig. 51.

bourhood of 1500°. Temperatures as high as 1650° have been attained.

Air entering at (*O*) passes through the tubes (*T*) into a collecting chamber (*P*), and thence into the mixing chamber (*M*). Here it meets the coal gas, the flame is formed and ascends into the furnace chamber, which is placed at a higher level than the recuperator. From the combustion chamber the hot gases descend and pass through the recuperator, being forced to take a long zigzag course by the three baffles (*R*).

The recuperator contains nine courses of tubes, each course consisting of thirteen tubes, each tube being made up of four 8 in. lengths. To prevent the cracking and breakage of the tubes as the result of thermal expansion, shrinkage or other movements occurring in the furnace and the baffles, the latter are not attached rigidly to the furnace, but stand on the floor of the recuperator chamber on a layer of grog of a refractory clay. They are not fastened to the walls, but fit loosely in slots, the leakage through these crevices being very small. The joints of the tubes rest loosely on the baffles.

Magnesite bricks were found to fail rapidly in consequence of "spalling"; crude zirconia bricks lasted longer than the magnesite, but failed through the same cause. The zirconia bricks, however, were eminently successful from the point of view of heat conservation, the gas consumption of the furnace for a standard working temperature of 1500° being decreased from 1200 cu. ft. per hour to 720 cu. ft. per hour. A marked diminution in the temperature of the external walls of the furnace was noticed.

The furnaces described are constructed of good quality firebrick protected by a wash of carborundum made by mixing the powdered carbide with 5 per cent. of China clay, in the form of a slip, and applying this with a brush.

The draught used in the working of these furnaces is obtained from chimneys less than 35 ft. in height, forced draught, of low pressure, derived from a fan, only being resorted to in exceptional circumstances. The gas consumption of the kiln furnace described, running at a temperature of 1500°, was 600 cu. ft. per hour of town gas of approximately 500 B.T.U. The air temperature, where the air left the recuperator, was between 250° and 300° below that of the working chamber of the furnace. With the furnace running at 1400°, the row of tubes nearest to the furnace chamber attained 1200°, the second row 900°, and the third row 650°.

Careful control of gas and air supply was necessary. The atmosphere in the furnace when working at fullest efficiency should be slightly oxidising. The authors found it an advantage to use a carbon dioxide recorder on the flue gases as a means of securing a proper adjustment of gas and air.

F. W. H.

185. Regenerative Liquid Fuel Furnaces. A. M. Aubert, France (Brit. Pat. No. **120559**, October 10th, 1918, No. 16518. Convention date, October 22nd, 1917. Not yet accepted.)—In a tilting furnace having reversible regenerators at the ends, a pair of interchangeable connections is provided between each regenerator and the furnace, one suitable for the supply of air, and the other for the exit of the combustion products. As shown, each connection, *d*, *e* (Fig. 52), is in two parts, d^1, d^2, and e^1, e^2, on the regenerator and furnace respectively, and these parts are carried by sector plates, *b*, *f*, mounted on pins, *c*, so that either the parts forming the air inlet connection or the combustion product outlet can be brought into operative position between the regenerators and the furnace. Each part consists of a metal casing with a refractory lining of suitable form. The sector plates are manipulated by tools inserted into sockets, *u* (Fig. 53), and their range of movement is limited by threaded pins, *w*, carrying locking-nuts. Mounted on each regenerator, *g*, g^1, is a melting tank, *p*, from which molten pitch passes through a filter, *q*, to a tank, *r*, with a valve-controlled delivery pipe, *s*. In addition to the regenerative chambers, *g*, g^1, a second set of chambers is provided. The reversing device consists of a double breeches-pipe with four pivoted valves. H. G. C.

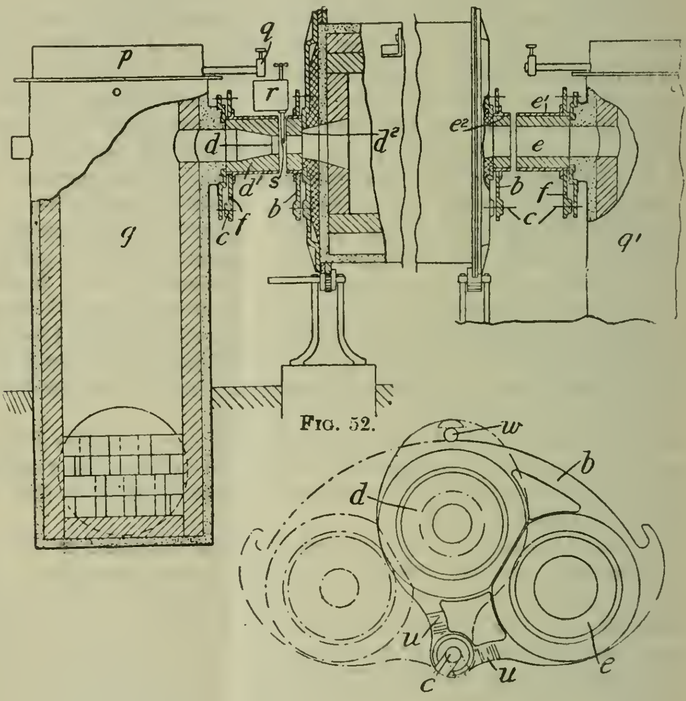


FIG. 52.

FIG. 53.

186. Fittings for Furnace Doors. W. Wragg (Brit. Pat. No. **120502**, February 22nd, 1918, No. 3161).—The door, *a* (Fig. 54), of a metallurgical or other furnace is provided with detachable flanges, *b*, which are formed with slotted lugs, b^2, preferably kinked, to engage recesses round the periphery of the main plate, *a*, and are secured by cotters, *c*. The plate, *a*, may be made of malleable iron or steel.

H. G. C.

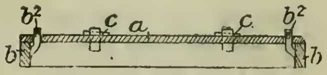


Fig. 54.

187. Preheating of Air. A. Hollis (Brit. Pat. No. **113534** April 4th, 1917, No. 4862).—In an air-, steam-, or gas-heating furnace, more particularly intended for superheating the air supply to a gas-producer, the furnace chamber is fitted with baffle-walls, *b*, *c*, Fig. 55, depending from the roof and springing from the floor respectively, and vertical portions of the heating-pipes are arranged to continue the line of the baffles, *b*. The ranges of vertical pipes, *g*, are connected together by headers, *d*, arranged symmetrically beneath the baffles, *b*, and headers, *e*, and U-bends, *h*. The furnace is heated by the combustion of gas and air in a chamber, *m*, at one end, and the products flow in counter-current to the air or gas to be heated. The air for combustion is heated in flues in the side walls of the furnace, and is supplied to a flue beneath a partition, *u*, having coned openings, *v*, in alignment with the burner nozzles, *p*.

H. G. C.

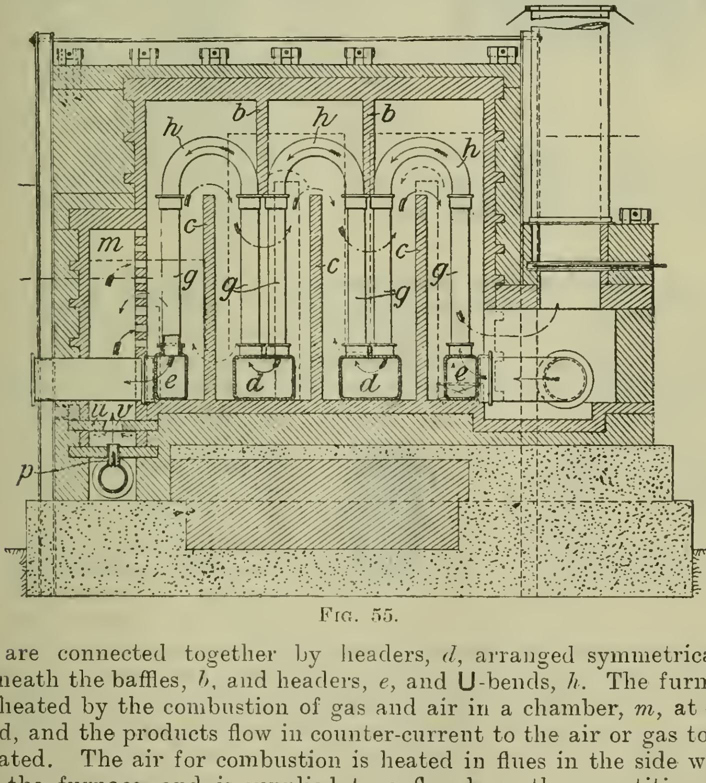


Fig. 55.

188. Regenerative Coke and Muffle Furnaces. Simon-Carves, Ltd., and J. H. Brown (Brit. Pat. No. **113696**, March 24th, 1917, No. 4255).—In a coke oven or muffle furnace installation with heating-flues between the walls of adjacent ovens, the air and gas for combustion are heated in passages situated between flues for the outgoing products of combustion. In the coke oven (construction shown) pairs of heating-flues are connected in the form of an inverted U and are provided with burner ports at the base of one limb, and outlets for the products of combustion at the base of the other, leading by passages, *F*, *f*, to flues, b^1, b^2, in regenerators situated vertically beneath the ovens. The air and gas are heated in the passages, *H*, *h*, of adjacent regenerators, and flow through sole flues, *E*, *e*, and burner ports, E^1, e^2, to the heating-flues. The regenerator passages are preferably baffled by chequer brickwork. A portion of the air may be mixed with the gas to be heated, and passages, *O*, beneath the heating-flues may be provided for the supply of rich coke-oven or other gas. H. G. C.

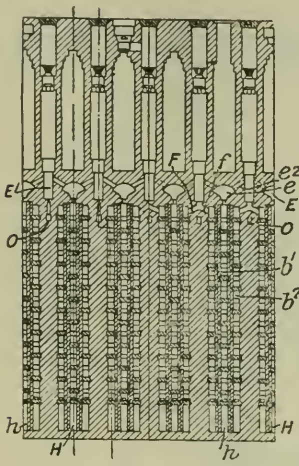


Fig. 56.

189. Atmospheric Gas Burners. Fletcher, Russell & Co., T. W. Fletcher and W. Banks (Brit. Pat. No. **113355**, March 27th, 1917, No. 4413).—The detachable burner nozzle, *d* (Fig. 57), is supported on a flange, *f*, on the secondary rectangular box-shaped mixing chamber, *c*, of a furnace burner, and is provided with a depending extension, *g*, projecting into the mixing chamber, *c*, and open at its lower end or provided with slits or saw cuts, *h*, for the passage of the gaseous mixture. The joint between the rim on the nozzle and the flange, *f*, is made by an asbestos washer or suitable cement. The nozzle may have one or more orifices, and may be made of steatite or cast iron. A central tube, *j*, may be arranged within the nozzle, *g*, and its upper end may be flush or extend above the orifice of the nozzle; in the latter case, the upper edge may be flared outwardly. The removal of dust, etc., from the tube, *j*, or the admission of air to it may be effected by means of sliding doors, *k*. When the nozzle, *d*, fits the tube, *j*, the body of the nozzle is provided with slits or saw cuts for the passage of the gaseous mixture. H. G. C.

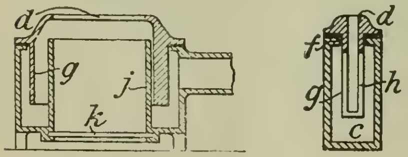


Fig. 57.

190. Removing Clinker from Furnaces. C. Crockwood and S. J. R. Allwood (Brit. Pat. No. **113190**, April 24th, 1917, No. 5716).—The non-combustible residue which collects at the sides of boiler and other furnaces is removed by means of an endless chain or toothed-like conveyor, 6 (Fig. 58), some or all of the links, 11, of which carry teeth or cutters, 12, which may be shaped as shown in Fig. 59, and which have overlapping joints so as to prevent clinkers from falling between them. The chain passes around rollers, 9, 10, and a driving sprocket, 7, and is supported on its upper run on a skid bar, 8. The clinker so cut off and removed is delivered by an oscillating discharge lock, 13, to a quenching receptacle clear of existing ash-pits and boiler settings. Instead of an endless chain, a reciprocating or oscillating toothed bar with cutters may be used together with a separate conveyor. H. G. C.

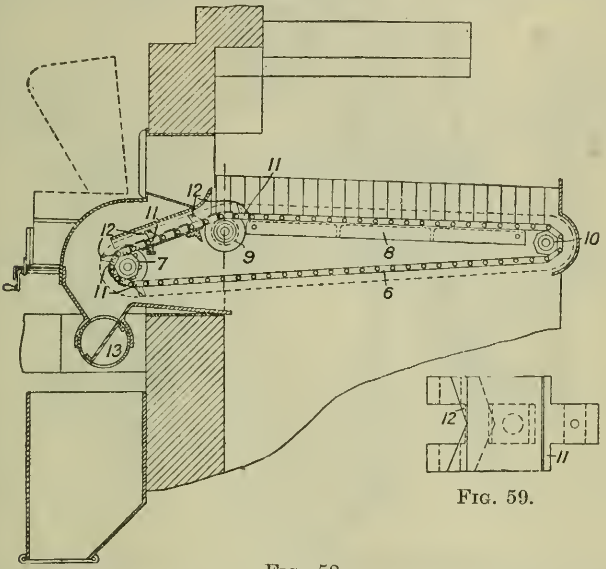


Fig. 59.

Fig. 58.

191. Charging Gas Producers. E. W. Harvey and E. N. Wright (Brit. Pat. No. **113203**, May 10th, 1917, No. 6626). —The shoot, *A* (Fig. 60), is mounted on trunnions, 2, 3, in bearings and carried by a casing, *E*, supported on rollers, 19, and rotated by a worm, 22, and worm-wheel. The casing is sealed at both ends by troughs, 7, 15, both of which are protected from falling material, the upper by a down-turned flange, 13, and the lower by an extension of the casing. To oscillate the shoot, an arm, 5, is fixed to one of the trunnions, and within a slot in this arm works a pin on a crank-disc, 27, which is rotated by the engagement of a bevel-pinion, 33, with a fixed rack, 34. The feed hopper, *G*, and delivery device, *D*, are carried by a casing, *F*, supported in a standard, *H*. The delivery device, *D*, is rotated from the worm-shaft, 23, through a crank-disc, 42, link, 40, and a slotted lever, 38, which carries pawls engaging ratchets on the drum shaft.

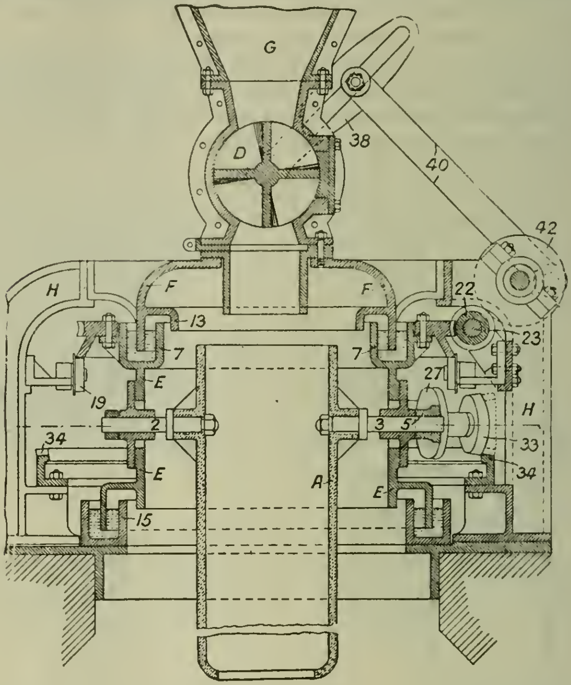


Fig 60.

The lower end of the shoot, *A*, is bent in its plane of oscillation. Specification 21382/14 is referred to. H. G. C.

192. Gas Producers. J. Stewart (Brit. Pat. No. **113182**, April 10th, 1917, No. 4982).—The rotary conical base of a gas-producer is formed with two or more grids or grates in the form of internally projecting pockets, 14 (Fig. 61). Fixed water-cooled stirrers or pokers, 19, are provided, having arms extending over and under these grates. An inlet for air, or air and steam, is provided at 24 between the stationary body of the producer and

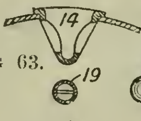


Fig 63.

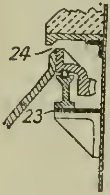


Fig. 62.

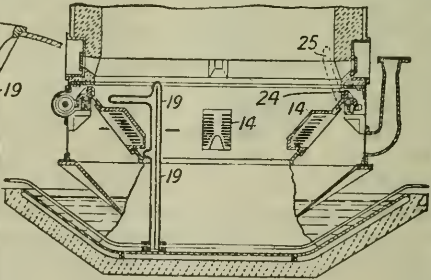


Fig. 61.

the top of the rotary base. This inlet may be divided off from the ash-pit by a plate, 23 (Fig. 62), on which the ball race of the bearing for the rotary base is mounted as shown in Fig. 63. The rotary base may carry upwardly projecting stirrers as indicated by dotted lines to 25 to agitate the fuel. H. G. C.

193. Furnaces for Utilising Powdered Fuel. H. Batchelor, U.S.A. (Brit. Pat. No. **120522**, May 17th, 1918, No. 8285).—Finely powdered coal dust and heated air are mixed together in predetermined proportions, according to an analytical determination of the carbon and hydrogen content of the coal, and the mixture is then discharged continuously into a combustion chamber in the presence of heat. As shown in Fig. 64, the supply of fuel to the mixing chamber, 20, is effected by the flow of previously heated air under pressure which drives vane wheels, 14, secured to the shaft of a rotary recessed drum feeder, 16, a variable frictional resistance being controlled by a wingnut, 25. From the mixing chamber, the mixture passes beneath the grate, on which is supported a mass of refractory material, 24. At starting, the mixture is ignited by a burner, 24*a*. H. G. C.

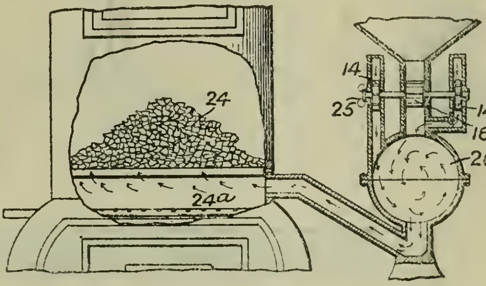


Fig. 64.

194. Metallurgical Reheating Furnaces. E. J. W. Richards and W. Shane (Brit. Pat. No. **120469**, December 3rd, 1917, No. 17844).—Metal-heating, annealing, welding, and like furnaces are constructed with a waste-gas chamber, 8 (Fig. 65), beneath the hearth, and with an air-heating chamber, 9, below, from which air passes through vertical passages, 6, to a gas- and air-mixing chamber, 3, arranged between the gas-producer, 5, and the furnace chamber. The gases from the mixing chamber pass downward to the furnace chamber. Gas enters the mixing chamber through ports arranged above the air-inlet ports. H. G. C.

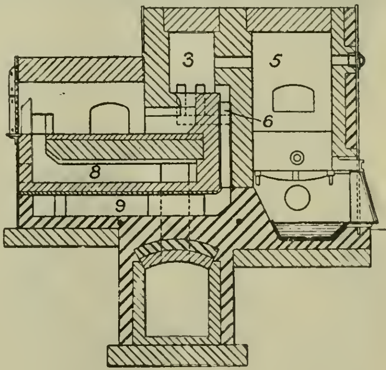


Fig. 65.

195. Reversing Valves for Regenerative Furnaces. E. J. W. Richards (Brit. Pat. No. **121316**, December 3rd, 1917, No. 17843).—Gas- and air-reversing valves for regenerative furnaces are constructed with a cylindrical chamber or bell, 1 (Fig. 66), having a diametral division wall, 2, which is seated in an annular water trough, 3, having cross troughs, 4, dividing the inlet and outlet ports. The chamber, 1, is rotated, and lifted and lowered at the same time, by the action of inclined portions, 6, of an interrupted flanged ring, 5, attached to it, which ride over rollers, 7, mounted on fixed supports. The division wall, 2, is thus lifted out of one cross-trough and lowered into the other. Spring devices are provided to take the shock when the chamber, 1, is lowered. These may consist of blade springs, 15, adapted to bear on the rollers, 7, or of spring-mounted rollers, on which the flanged ring, 5, rests when in its lowest position. H. G. C.

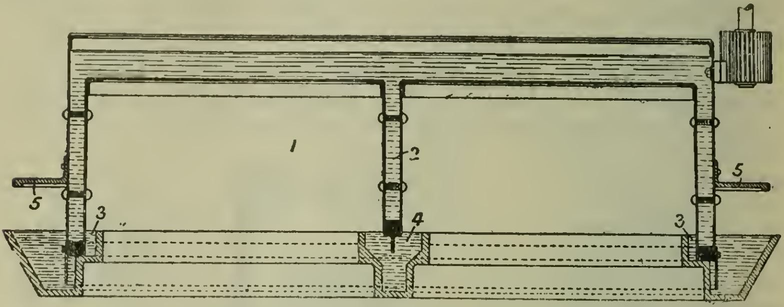


FIG. 66 (*a*).

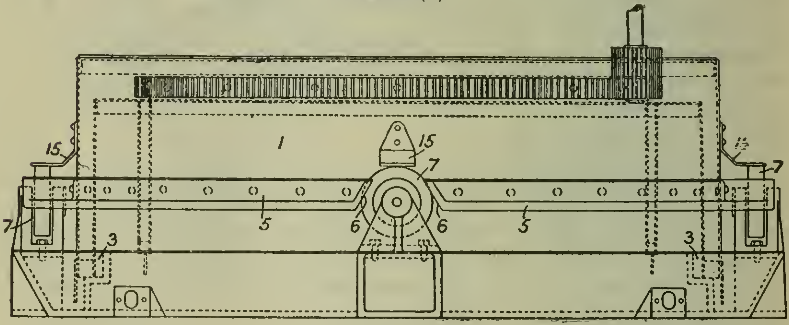


FIG. 66 (*b*).

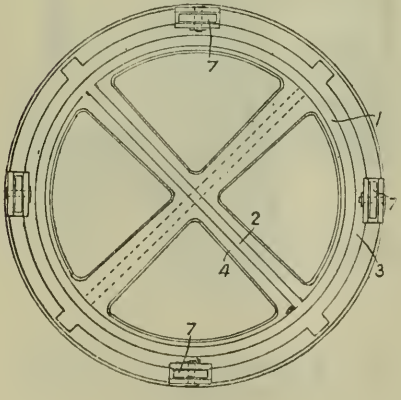


FIG. 66 (*c*).

196. Electric Furnaces. C. H. von Baur (Brit. Pat. No. **120444**, November 10th, 1917, No. 16507).—Two-phase current is supplied to three pendent electrodes, C, C^1, C^2 (Fig. 67), arranged in a furnace of oval shape in plan, such that the distance of each electrode from the walls is proportional to the current traversing it. As shown, the walls comprise circular portions of radii $1 : \sqrt{2} : 1$, preferably joined by tangential portions. Each outer electrode preferably enters the furnace through a partly spherical block, *F*, seated in the roof, so as to allow of movement over the surface of the charge. The blocks are provided with handles, F^2 (Fig. 68), and asbestos packing, *G*. Arcs are maintained between the electrodes and the slag, and not directly between electrodes. The furnace has charging and working doors, *J*, a spout, *H*, and a curved base unprovided with electrodes. H. G. C.

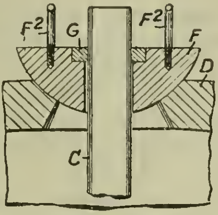


Fig. 68.

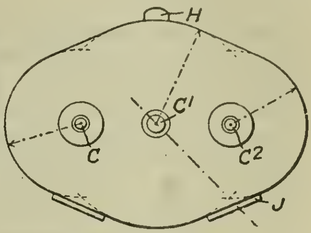


Fig. 67.

197. Glass Re-heating Furnaces. Burdins, Ltd., and W. Burdin (Brit. Pat. No. **121100**, August 9th, 1918, No. 12956).—In a glory-hole furnace for re-heating glass bottles, etc., the holes, *j*, for the reception of the bottles open into spaces, *c* (Fig. 69), separate from, but in communication with, a combustion chamber *a*, heated by a liquid-fuel or oil-gas burner. From the spaces, *c*, flues, *d*, lead the combustion products either direct to the atmosphere through the flues, *e*, or to the chamber, *f*, containing the air-supply pipe, *g*, for the burner. The flues, *d*, are restricted in size, so that a portion of the combustion products is forced to escape round the bottles through the holes, *j*. H. G. C.

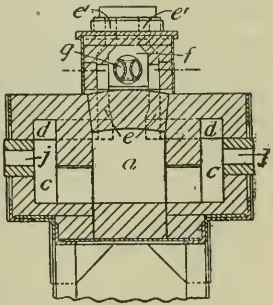


Fig. 69.

198. Cooling Device for Gas Ports. O. C. Bockman, Norway (Brit. Pat. No. **121111**, May 17th, 1918, No. 8274. Convention date, November 27th, 1917. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—The walls of a port or passage, through which hot gases are conducted, are protected by a screen of cool gas delivered through tangentially-arranged orifices. In the construction shown, the cool gas is delivered through a hollow bushing fitted in the port, and the arrangement of the orifice is such that an annular screen of cool gas is formed between the walls of the port and the centrally-delivered hot gas. The cool gas may be neutral or active with regard to the hot gas or the furnace charge. H. G. C.

199. The Basis and Methods of Pyrometry. F. Henning (*Phys. Zeitschr.*, 1919, **20**, 34).—Thermodynamical considerations form the theoretical basis of all methods of measuring temperature. A brief exposition by the author of the thermodynamical behaviour of an ideal gas was followed by an indication of its use in gas thermometry. Actual gases, however, deviated somewhat from the laws which the ideal gas was assumed to obey, so the theory had to be modified. Even with this alteration, gas thermometers were not practically applicable to the measurement of high temperatures, so the conception of black body radiation was introduced. The laws of Kirchhoff, Stefan, Wien, and Planck were used to develop at some length the theory arising from this conception, and an explanatory reference made to Planck's constant.

The greater part of the paper was devoted to the methods of measurement of temperature and to the instruments used. The latter could be divided into two groups, namely, contact thermometers and radiation thermometers. The former had an upper limit of applicability at that temperature at which their behaviour was uncertain on account of irreversible changes of the thermometric substance, as, for example, the boiling of the mercury in a mercury-in-glass thermometer. For very high temperatures radiation pyrometers were always used.

Among contact thermometers the author mentioned the gas thermometer, the mercury thermometer (which in the case of the gas-filled type made of Jena glass 59^{III} could be used up to 600), and the thermo-element. The theoretical basis of the last-named was explained. The following table was given of the electromotive force, in millivolts, obtained with various couples when one junction is at 500° and the other at 0°:

Couple.	E.M.F.	Couple.	E.M.F.
Pt/90% Pt 10% Rh...	4·21	Fe/Constantan	27
Ni/90% Ni 10% Cr ...	10·0	Ag/Constantan	28
Fe/Ni	12·0	Cu/Constantan	28

It was stated that either of the formulæ $e=at+bt^2$ or $e=at^b$, expressing the *E.M.F.* as a function of the temperature, may be used for extrapolation, provided the temperature to be ascertained was not too high. In this group also were classed resistance thermometers, which depended on the variation of the electrical resistance of a metal wire with temperature. If the wire was of platinum such an instrument would give a reading correct to 0·01° up to 500°.

Radiation thermometers might be of two kinds, Fery's pyrometer being a specimen of one kind. In this and similar instruments the radiant heat from the hot body or furnace was concentrated on an iron-constantan thermo-element, to which was attached a blackened silver plate. This plate increased the absorption of the heat rays and the *E.M.F.* produced by the consequent heating of the thermo-element provides the means of measuring the temperature. The second kind of radiation thermometer was the optical pyrometer, of which there were several modifications. Two of those were mentioned as typical. The first is that of Le Chatelier, based on the photometer of Lummer and Brodhun. The other was devised by Holborn and Kurlbaum, and in this case the hot body was viewed directly. In all its variations the optical pyrometer consisted essentially of a means of equalising the intensity of the light, of a definite wave-length or spectral band, radiated by the hot body, with that of the same wave-length emitted by a standard. The theory of the two instruments to which reference was made was developed.

The theoretical basis of all radiation pyrometers was that of "black body" radiation. In actual practice, however, perfect black body radiators were not encountered, and the author discussed the modifications of the theory which were necessary in order that the results obtained therefrom might be practically applied. Mention was also made of the difficulty of measuring the temperature of transparent bodies, such as gases, by radiation thermometers.

J. R. C.

VIII.—Chemical Analysis.

200. Sampling Granular and Like Materials. L. J. Riley (Brit. Pat. No. **121084**, June 14th, 1918, No. 9799).—A device for obtaining a sample of dry or moist granular and like materials throughout the whole depth of the heap or other bulk consists of a tapered tube (Fig. 70) open at both ends and having a removable handle passed through holes, *c*, *c*, in the side of the tube near the larger end. The tube is inserted in the heap and then carefully withdrawn, and the sample thus obtained removed through the larger end of the tube.

H. G. C.

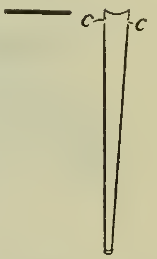


Fig. 70.

IX.—Machinery for the Working of Glass.

201. Glass-shaping Machines. Hartford-Fairmont Co., U.S.A., assignees of K. E. Peiler and E. H. Lorenz (Brit. Pat. No. **120907**, November 11th, 1918, No. 18460. Convention date, November 20th, 1917. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—Relates to glass moulding and blowing machines of the rotary-table type, and particularly to duplex or multiple machines, and consists of interlocking mechanisms to secure the proper co-ordinate action of the parts and to allow any single element to be operated independently of the others.

The invention is described as applied to a machine with two rotary tables, 4 (Fig. 71), similar mechanism being fitted to both tables. The tables carry the usual moulds, 5, and are given an intermittent rotation so as to stop at the charging, pressing, and delivering positions. Fig. 72 shows, in plan, the mechanism arranged below the left-hand table, the corresponding mechanism being arranged under the right-hand table. The driving-shaft, 8, actuates, through worm and screw-gearing, cams, 13, 14, the former of which gives motion to a rocking lever, 16 (Fig. 72), and the latter acts against a roll, 20, carried by the lever. The lever, 16, actuates an arm, 22, connected by a link, 23, with an arm, 24, pivoted on the hub of the table and carrying a spring bolt, 26, adapted to engage any one of a series of notches, 28, formed in blocks fitted to the underside of the table. The notches also serve to receive a locking-bolt, 40, for holding the table stationary. The oscillating lever, 16, drives the table at gradually increasing speed for the first half of its motion, and during the second half is retarded by the cam, 13. The bolt, 26, is withdrawn by an arm, 36, actuated by a cam, 34, and adapted to hold it retracted during the return movement of the arm, 24, but allows the table to be moved by hand. The locking-bolt, 40, is withdrawn by a lever, 43, actuated by a cam, 47. The bolts, 26, 40, are interconnected so that, if the latter does not properly engage a notch, the arm, 36, cannot move to release the former. Both bolts may be released by a hand-lever, 51, the inner end, 52, of which holds back the lever, 43, thus leaving the table free to be rotated by hand. The bolt, 26, can be put out of action independently of the bolt, 40, by operating a treadle connected to

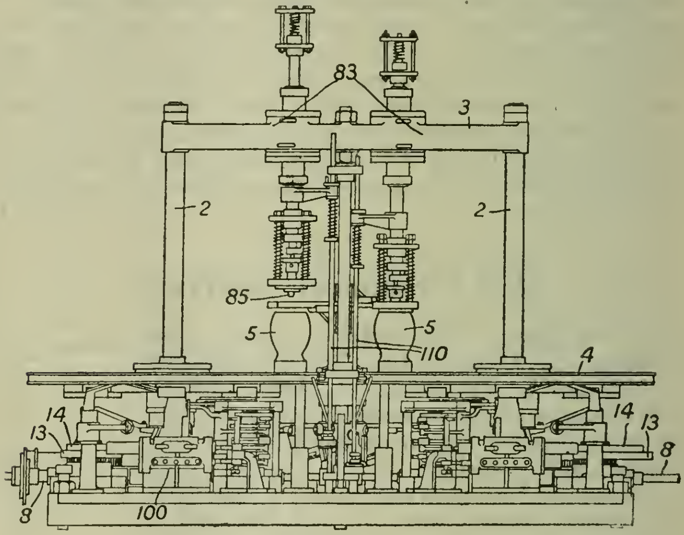


Fig. 71.

a rod, 55, pivoted to an arm, 54, fixed to the controller arm, 36. The table is fitted with an adjustable band brake actuated by a cam connected with the cam, 34, that actuates the bolt, 36. The moulding-plungers, 85, are of usual construction and are actuated by pneumatic cylinders, 83, mounted on a cross-bar, 3 (Fig. 71), carried by standards, 2. Air is supplied to the cylinders from a valve-chest, 100, through an automatically-operated valve, but the valve may be closed by hand when required.

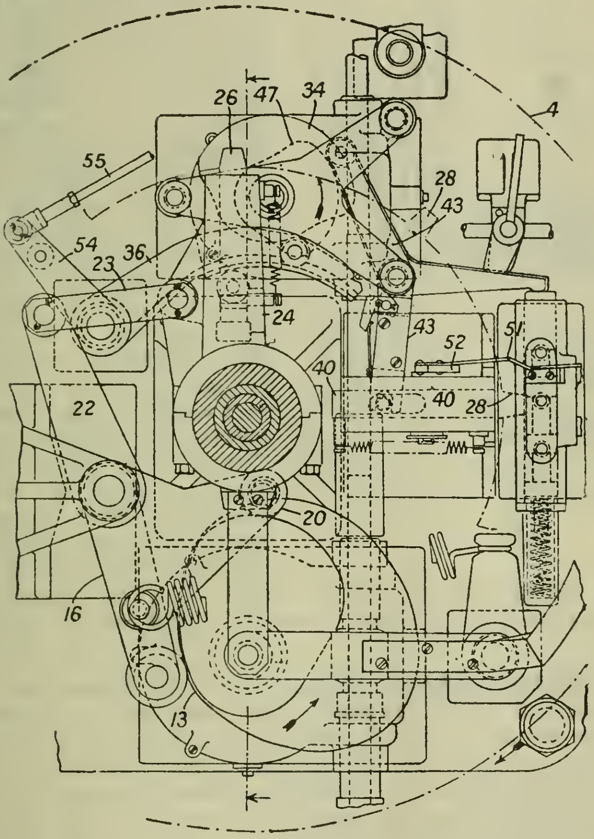


Fig. 72.

The cam operating the valve interacts with the cam, 47, actuating the locking-mechanism, so that the plunger cannot descend if the bolt does not properly engage. Rods, 110, are mounted so as to move vertically with the plungers, and are connected to the table-driving mechanism, so that the table is stopped if the plunger does not rise owing to its sticking to the glass, or, if the plunger should descend while the table is moving. The plungers are cooled by air circulation. The transfer of the blank may be effected auto-

matically, and a blowing-head may be fitted to the machine and connected with the driving mechanism by interlocking mechanism.
H. G. C.

202. Semi-automatic Bottle Making Machine. E. H. Langwell and E. Durand (Brit. Pat. No. **114193**, March 21st, 1917, No. 4114).—Relates to a manually-operated machine for blowing glass bottles, and of the kind in which the suction and preliminary blowing in the parison mould are effected by two pistons working in unison in separate cylinders, to one of which compressed air is admitted by a four-part valve. According to the invention, a parison mould without a removable cover is used, and the neck ring, F, is made in two parts hinged together with a lug, f^1, on each part to support the ring in position in the parison and finishing moulds. The pistons, which work in cylinders, A, B, are connected by pipes, b^2, b^3, to the valve, D, which is operated by means of a handle, d. The exhaust air may be used for cooling the parison mould, E. The plunger of the parison mould is operated by a treadle, H, and rod, h^1, as usual.
H. G. C.

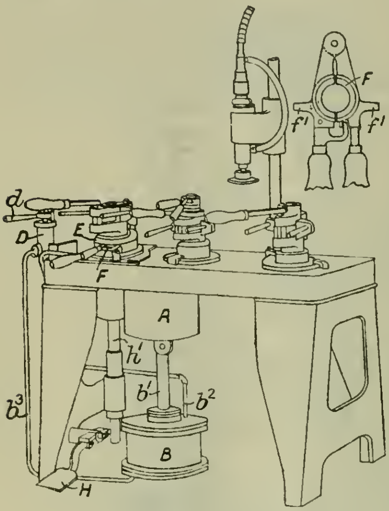


Fig. 73.

203. Bottle Making Machine. T. B. Kitson and G. O. Togue (Brit. Pat. No. **114477**, April 5th, 1917, No. 4927).—In apparatus for making glass bottles and jars, in which the parison and finishing moulds are arranged alternately round a revolving table, all the operations of suction and blowing and of the opening and closing of the moulds, except the transfer of the parison, are effected automatically and controlled by two cams only. A barrel cam, D (Fig. 74), engaging rollers, A^1, on the underside of the table, A, rotates the table step by step; slides, C, operated by cams, d, d^2, on the central pillar, B, cause the opening and closing of the parison and blowing moulds, a, b. The divided neck-rings, e, are secured to arms, e^1, hinged together at e^2, and are adapted to fit in recesses in the brackets, a^2, b^2. The sliding bracket, g, carrying the plunger is moved up and down on a guide, g^1, by a lever having two spring-controlled arms, g^2, g^3, mounted on a pivot, g^4, and operated by collars, g^6, on a central spindle, h, which is reciprocated vertically by an arm, D^8, on a shaft, D^6, carrying a lever, D^5, which engages a cam, D^2, on the end of the barrel, D. Fig. 75 shows the plunger, *f*, and suction arrangement for the parison moulds. The suction pipe, f^{11}, is connected to a cup, f^5, which is supported in an opening in the annular flange, g^7, of the bracket, *g*, by springs, g^8, upward movement being limited by a flange, f^7, on the cup. A

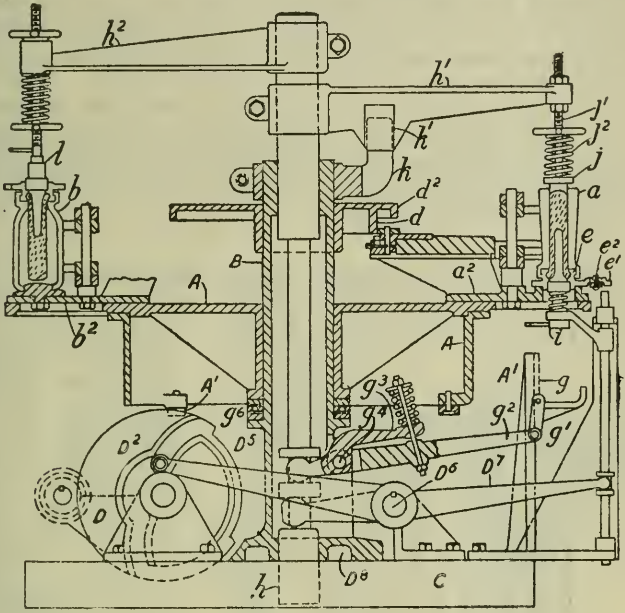


FIG. 74.

block, f^2, on the plunger stem, f^1, is provided with an air-groove, f^8, from which a passage, f^9, leads to an annular channel, f^{10}, which communicates with the mould channel. e^4, by a fine annular slit, e^5. A spring, f^4, is arranged between the block, f^2, and the cup, f^5. The cover, *j* (Fig. 74), of the parison mould is carried by a cushioning-spring, j^2, at the lower end of an adjustable screw, j^1, on a radial arm, h^1, adjustably secured to the spindle, *h*. Rotary movement of the pillar, *h*, and arm, h^1, is prevented by a bent arm, *k*, carried by the pillar, *B*, and engaging a socket, k^1, on the arm, h^1. The adjustable blow-cap, *l*, is carried by a radial arm, h^2, which is adjustable on the spindle, *h*, in order that it may be set so that a blowing-mould does not reach it until the parison has equalised its heat after leaving the parison mould. In operation, the parison mould having been

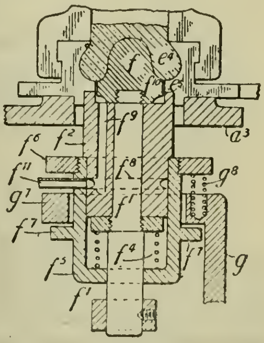


FIG. 75.

charged with glass, the plunger, *f*, is lowered by the arm, D^7, thus cutting off the suction by the block, f^2, being pressed upwards by the springs. The table then advances a step, whereupon the cover, *j*, descends on to the inverted parison mould and the preliminary blower, *i*, is raised by the arm, D^7, to blow the parison. In the next position, the parison mould having been opened by its cam, the parison is transferred by hand to one of the open blowing-moulds. During the next step, the blowing-mould is closed by the cam, d^2, and the blow-cap, *l*, descends on to the neck-ring, e^1, and the bottle is blown. As the table moves through the last step and completes a revolution, the blowing-mould is opened by its cam and the finished bottle is removed by the operator. H. G. C.

204. Machinery for Glass Bottle Manufacture. SHAW-BRUNER, LTD., G. C. PYLE, and G. C. DAGER (Brit. Pat. No. **114709**, June 1st, 1917, No. 7879).—In apparatus for making hollow glassware the parison is held at one end by the neck-mould and at the other end by a centring device or bottom mould which serves to support the parison during its transfer from the parison mould to the blowing-mould and whilst being blown in the latter. As shown, the parison mould, (*a*) (Fig. 76), and the blowing-mould, *b*, are both carried by the same set of arms or jaws, *c*, *d*, which are mounted on a hinge-pin, *e*, having at its lower end a collar, *f*, and slide, *h*, to engage a guideslot, g', in the base, *g*. The divided neck-mould, *i*, is carried by arms, *j*, mounted on a pin, *k*, on the top, l', of the bracket, *l*, on the base, *g*. The base-ring or bottom mould, *o*, fits into a shallow, elongated recess, o', in the bottom of the double mould. When the parison, a', is to be blown, the mould, (*a*), is opened and the double mould is moved until the

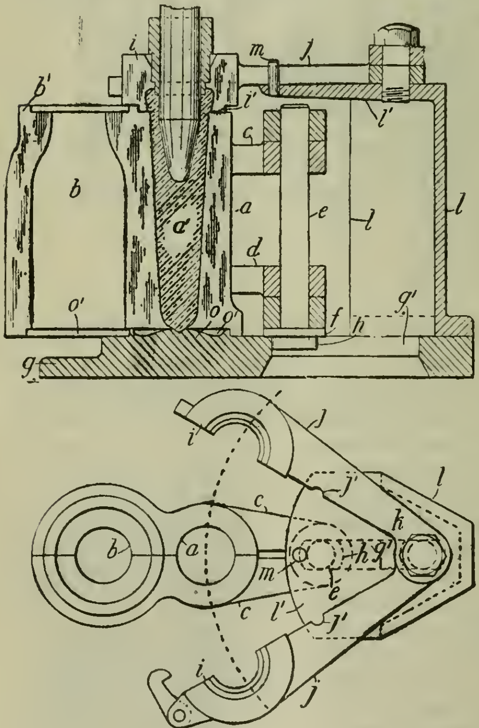


FIG. 76.

slide, h, reaches the other end of the slot, g'. When the arms, j, are close together, recesses, j', in the arms embrace a pin, "m," on the part, l'. A short reduced portion, i', of the neck-ring, i, engages a collar, b', at the top of the mould, b. The mould may be stationary, and the parison carriers move from one position to the other. The arms and guides of the double mould may be carried in a reversible frame, so that the parison can be inverted.

H. G. C.

205. Glass Bottle Machines. W. Forster (Brit. Pat. No. **114678**, April 21st, 1917, No. 5604).—Relates to machines for making glass bottles, etc., and of the type having a revolving frame or plate carrying parison moulds on opposite sides of its horizontal axis and two sets of neck or mouth mould carried on the terminals of a hollow double arm. The machine is constructed so as to have a vacuum and a positive air pressure in the neck or mouth mould parts alternately while in their opposite positions, and air is constantly blown on to the parison moulds for cooling them. The

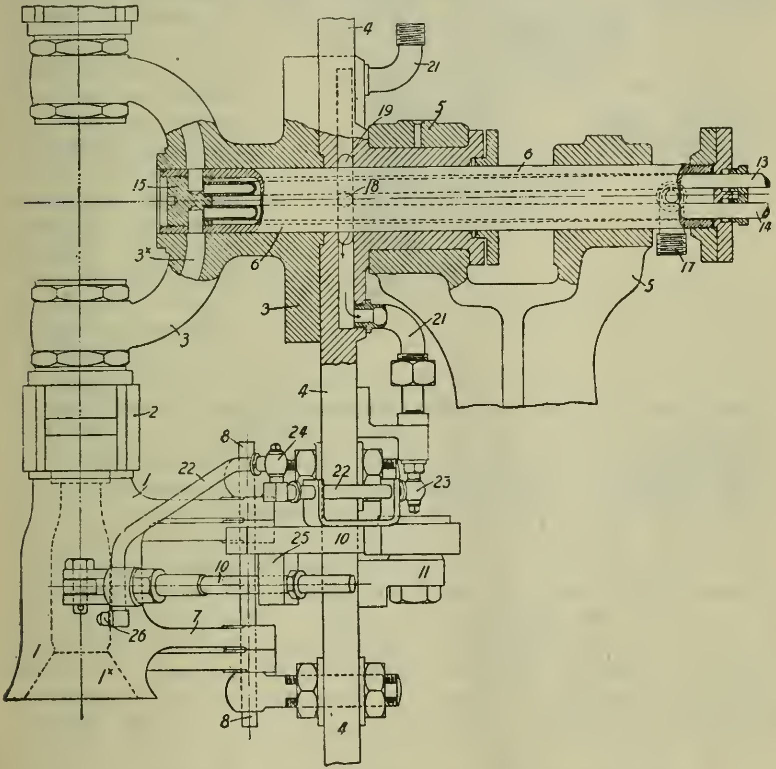


Fig. 77.

neck-rings, 2 (Fig. 77), are carried by a hollow double arm, 3, on the revolving frame, 4, which is mounted on a stationary hollow shaft, 6, within bearings, 5. The parison moulds, 1, are mounted by arms, 7, on pins, 8, carried by the frame, 4, and are opened and closed by arms, 10, mounted on pivots, 11. Tubes, 13, 14, extending through the shaft, 6, into a ported plug, 15, at the end of the shaft supply suction and compressed air to the passages, 3*, in the arms, 3, when the latter are in the upper and lower positions respectively. Air for cooling the moulds is supplied by a pipe, 17, to the shaft, 6, and passes by a port, 18, into an annular port, 19, in the frame, 4, whence pipes, 21, lead to double articulated pipes, 22, with nozzles, 26. The joints, 23, 24, of the pipes 22, are axially in line with the pivots, 11, and the joints, 25, of the arms, 10, respectively. In a modification (Fig. 78) a circular ported plate, 30, attached to the swing frame, 4, is formed with annular recesses, 31, 32, in its face to work over stationary rings, 33, 34. Compressed air passes from a connexion, 17, to an annular port, 35, in the meeting faces of the recesses, 31, and ring, 33, and then by ports, 36, to the joints, 23, of the cooling air-blast pipes, 22. The vacuum pipe, 13, is connected to the upper part of the ring, 34, and pipes, 37, on opposite sides of the axis of the plate, 30, lead to the passages, 3*, of the arms, 3, so that, when an arm is in the upper position, its passage, 3*, communicates with vacuum. H. G. C.

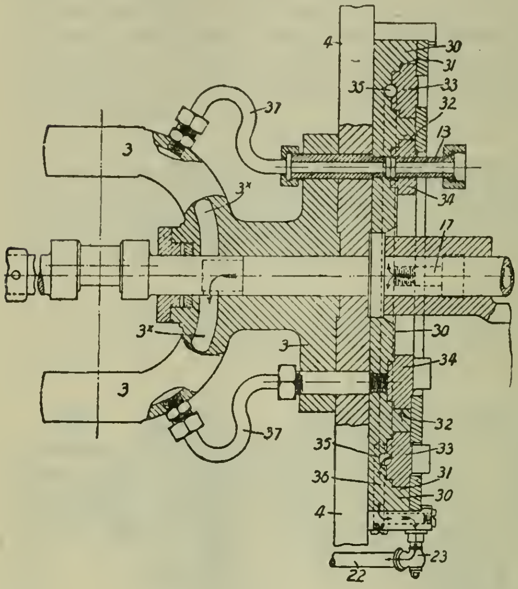


Fig. 78.

206. Machinery for Drawing Glass Cylinders. A. E. Spinasse, U.S.A. (Brit. Pat. No. **114819**, November 26th, 1917, No. 17474. Convention date, April 12th. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act).—In drawing glass cylinders, the hollow bait used is coated on the glass surfaces of contact with an adhesion-preventing substance. The bait is preheated to a temperature at which molten glass adheres to it, and the coating may be applied before, but is preferably applied after, heating. Resin, tallow, oils, and waxes, or compounds of these materials, are mentioned as suitable substances for coating an iron bait heated to about 400° F., and powdered lime, magnesia, etc., for a bait heated to about 900° F. Lime in the form of paint, whitewash, or some oily emulsion of clay, paint, lime, or graphite, which may be in powdered or pasty form, is stated to be most suitable. The coating may be shaped or moulded into the form of an envelope and slipped on to the bait. The bait may be made of cast iron, chrome, or nickel steel, etc. Fig. 79 shows a sectional bait with the sections, 4, supported by pins, 3, in socketed ears, 2, on the air-pipe, 1. Each section is fitted with a handle, 5, and there may be slots or openings, 6, between the sections. A bowl-shaped open-bottomed bait is shown in Fig. 80, the sections, 4, being carried by spring arms, 9. In the form shown in Fig. 81 the pivoted sections, 4, are hook-shaped and supported by rods, 9^1, from a collar, 10, a weighted ring, 11, serving as a stop to limit the swing and keep the sections loosely together. Air is introduced through openings, 8, in the arms of the T-shaped top. s, of the bait handle. Fig. 82 shows a sectional bait provided with out-turned hooks to engage the cylinder cap on its interior. A bait made of spring metal with the sections integral with the air pipe may be used. The invention is applicable to drawing-glass sheets. H. G. C.

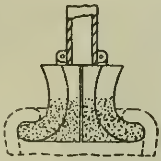


FIG. 82.

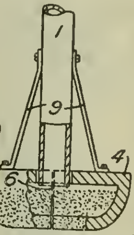


FIG. 80.

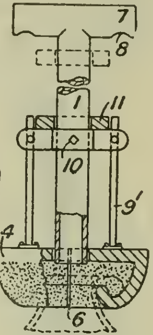


FIG. 81.

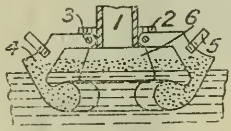


FIG. 79.

207. Glass-blowing Moulds.

L. N. BRUNER and S. D. OLSEN (Brit. Pat. No. **120416**, November 2nd, 1917, No. 15993).—Relates to means for opening and closing the blowing moulds of blowing-machines, so that they are held firmly closed without locking devices. The mould is divided longitudinally as usual, and the halves are

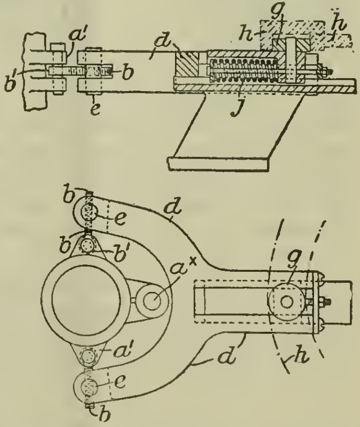


FIG. 83.

mounted on a fixed axis, a^* (Fig. 83). The halves are operated by a forked slide, *d*, the ends of which carry pivoted pins, *e*. Connecting links, *b*, adjustably mounted in the pins, b', are connected to lugs, a', on the mould halves, and are disposed so that, when the mould is closed, they are radial or almost radial thereto. The slide, *d*, is actuated by a stationary cam, *h*, through a roller, *g*, and a spring, *f*.
H. G. C.

208. Drawing Glass Cane and Tubing. J. Gray, General Electric Co.; Schenectady, New York, U.S.A. (Brit. Pat. No. **113892**. June 12th, 1917, No. 8400).—Relates to apparatus for drawing cane glass and tubing of the form described in Specification 105285, and consists of driving the chilling, cutting, and delivery devices through mechanism independent of the chain conveyor, in order that the machine may be driven at greater speed. A motor drives the chain carrier, 4 (Fig. 84) described in the prior specification, and independently actuates mechanism carried by a bracket, 15, on the standard, 3, for operating the chilling, etc., devices. A shaft, 17, mounted in the bracket and driven through gearing as shown from a vertical shaft, 10, carries an eccentric, 20, and a crank-arm, 33. The eccentric actuates the cutting devices, 23, 24, through links, 22, 29, and bell-crank levers, 21, 28, the operation of the cutters being similar to that described in the prior specification. The delivery devices, 8, carried on the pivoted frame, 32, are actuated by a link, 35, and arm, 34, by the crank, 33. The cooling and chilling devices are initially adjusted by a hand-wheel, and are afterwards automatically actuated by ratchet mechanism operated by a rod, 40, from the arm, 34.
H. G. C.

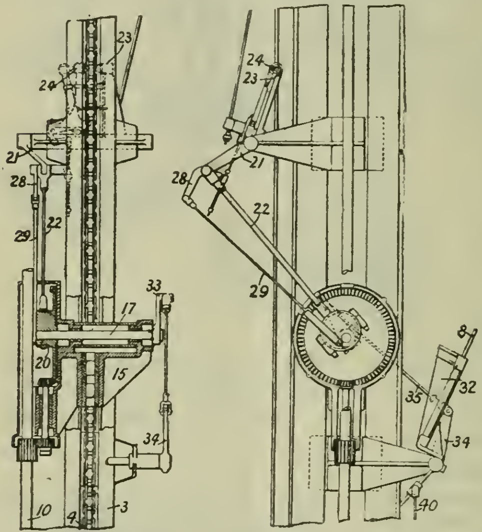


Fig. 84.

209. Feeding Device for Glass Bottle Manufacture. R. E. McCauley, U.S.A. (Brit. Pat. No. **113665**, March 2nd, 1917, No. 3075).—Relates to a method of, and means for, controlling the supply of molten glass from a furnace or tank to the parison moulds used in the manufacture of bottles and jars. The glass flows from the main tank or furnace into an extension, 4 (Fig. 85), which contains a vertical refractory cylinder or tubular member, 14, the lower open end of which is situated below the surface of the molten glass and above the discharge orifice, 15, but does not close this orifice. The upper end, 19, of the cylinder is flared and held by a clamping-plate, 27, bolted to the upper plate, 8, of the extension, 4; and a plate, 25, carrying tubes, 23, 24, fitted with valves, 32, 34, is held on top of the cylinder by bolts, 26, engaging the plate, 27. The pivoted valve-operating lever, 36, is connected to the valves by rods, 33, 35. When the mould is charged with glass, the lever, 36, is operated to open the suction valve, 32, and close the vent valve, 34, so that the flow of glass is stopped and the mass of glass in the opening, 15, is drawn up and re-heated. On closing the valve 32 and opening the value 34 so as to reduce the vacuum in the cylinder, 14, molten glass flows from the orifice, 15. Heat may be applied through apertures in the extension, 4, to heat the glass in the extension and the cylinder, 14. The extension is preferably built of firebrick, and is held in place by upper and lower plates, 8, 9, and an end-plate, 10, which are held together by stay-bolts, 11, and supported by suitable braces, 13. A renewable fireclay dish, 16, with a central aperture is fitted to the orifice, 15, and held in place by retaining-plates, 17, 18, and screws. A cap, 20, with apertures, 21, 22, corresponding with the tubes 23, 24, is situated in the upper end of the cylinder, 14. H. G. C.

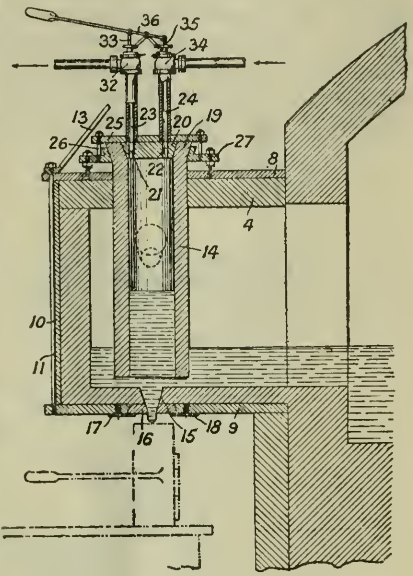


FIG. 85.

210. Grinding and Polishing Glass. PILKINGTON BROS. and F. E. SLOCOMBE (Brit. Pat. No. **120594**, October 10th, 1917, No. 14682).—Apparatus for grinding or polishing plate glass comprises two discs mounted on two horizontal shafts, which are out of line but approximately parallel, one at least of the shafts being driven and one or both of the discs being provided with sucker devices for securing glass thereto. As shown in Fig. 86, the apparatus comprises a disc, 1, fitted with suckers and mounted on a shaft, 3, driven by a motor, 11, and gearing, 9, 10. The second disc, 2, is mounted on a shaft, 4, supported in bearings, 6, 14, on a frame, 8, which is adjustable along guides, 15, 16, by means of a screw, 20, and may be given a slight angular adjustment by set-screws, 26, with heads bearing against ribs, 24, on the fixed underframe. The disc 1 is forced towards the disc, 2, by fluid pressure admitted to a cylinder, 13, and the pressure may be transferred to the opposite side of the piston periodically by a valve, 31, actuated by a cam, 30, on a shaft geared to the shaft, 3. At the separation of the discs, 1, 2, a valve controlling the supply of abrasive material is actuated. The cam, 30, is preferably shaped to give a rapid withdrawal of the disc, 1, and a gradual return. The axial movement may alternatively be effected by a cam acting directly on the shaft, 3. The exhaust passage for actuating the suckers on the disc, 1, passes axially along the shaft, 3, to a pipe leading to a pump. Abrasive material may be supplied to the disc 2 by a hole through its shaft, or by a pipe, 32, leading to an undercut ring, 33, at the back of the disc. It may be supplied also to the face of the disc by a spreading-plate, 27. The disc, 2, also may be provided with suckers for securing waste or other glass thereto, so that the glass surfaces may grind each other by means of abrasive supplied between them. The abrasive may be supplied through holes in the discs, the glass being arranged to leave gaps over these holes. Glass plates may be transferred to or from the machine by dummy discs fitted with suckers and with side-cramps for securing them to the

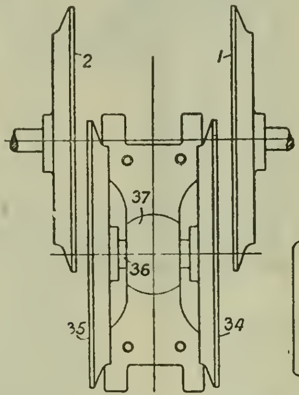


Fig. 87.

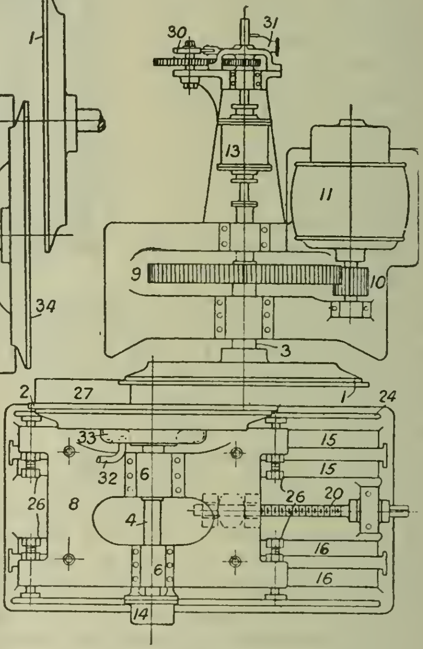


Fig 86.

machine discs during the release of one set of suckers and the application of another set. Two dummy discs may be used for reversing the glass sheets. The suckers on all the discs are arranged in the same relative positions to facilitate transference. In the arrangement shown in Fig. 87, a pair of discs, 34, 35, are mounted on a shaft, 36, running in a spherically-seated bearing, 37, placed between two driven discs, 1, 2. All the discs may carry suckers, those on the discs 34, 35 being exhausted by a pump and motor attached to the back of one of the discs, and current being supplied by slip-rings on the shaft, 36. Pressure cylinders similar to the cylinder 13 (Fig. 86), may be arranged for each of the discs, 1, 2, cylinders being controlled by the same set of valves.

H. G. C.

211. Feeding Device in Glass Manufacture. R. E. McCauley, U.S.A. (Brit. Pat. No. **114583**, October 20th, 1917, No. 15247).—The glass flows from the tank, 1 (Fig. 88), into a detachable extension, 2, the bottom of which is provided with a nozzle, 16, the upper edge of the nozzle rising above the level of the glass. A vertical cylinder, 19, is slidably mounted in the top of the extension, and can be raised and lowered by a hand-lever pivoted in lugs 21. Pipes 35, 36, communicate with the cylinder, and are connected respectively with a source of compressed air, or the atmosphere, and to a suction pump. At the commencement of the operation, the outlet is closed by a plug, 48, until the movement of a cam, 41, has opened the cylinder to the exhaust and closed the compressed-air pipe by valves operated by a lever, 39. The glass is drawn into the cylinder to a level, 49, and is discharged when the valves are reversed. A vacuum relief valve, 47, is arranged to prevent excessive exhaustion. The outflow synchronises with the movement of a rotary table, 42, carrying the moulds, 43. During the suction stage, the glass is drawn back into the nozzle so as to prevent chilling. The extension is composed of firebrick, and is supported by metal plates, 4, held together by rods, 7, and fixed to the tank by stays.

H. G. C.

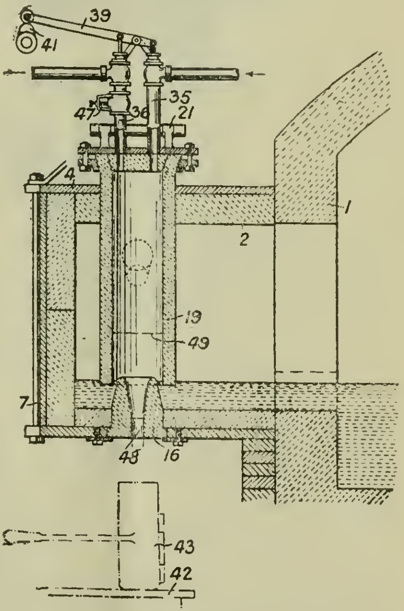


Fig. 88.

212. Automatic Flowing Device for Feeding Molten Glass. G. E. HOWARD, U.S.A. (Brit. Pat No. **120744**, August 10th, 1917, No. 11513).—Relates to the feeding of molten glass from tanks, furnaces, or other supply reservoirs to moulds, etc., and consists in continuously causing the glass to flow through an orifice in the reservoir, and acting on the glass, at or after it has passed the orifice, to vary the forces of suspension in the glass without checking, stopping, or reversing the flow of the glass through the orifice and separating or detaching the mass from the supply body. As shown in Fig. 89, a tube, 3, is mounted within the tank, 1, with its lower end projecting slightly beyond the discharge opening, 2. When suction is applied to the tube, the glass is drawn up inside it, the relative diameters of the opening, 2, and tube, 3, being such that the suction does not stop the normal flow of the glass through the annular orifice, 2′. As the globule, 6, elongates, the glass in the tube, 3, is forced out to fill the centre of the globule so that it assumes the form shown at 8. On again applying suction, the globule contracts at 9, whereupon it is cut off, the lower end or chilled portion, 11, being drawn up into the tube, 3, so that it is incorporated in the glass flowing down and around the tube. The end of the tube may be situated within the discharge opening or slightly above the bottom of the vessel. As shown in Fig. 90, the tube is replaced by a lateral passage, 12, formed in an offset, 13, of the reservoir, 1, and connected by a passage, 14, to a source of vacuum. The passage, 12, takes the glass from and adds it again to the sides of the drop. In another arrangement, Fig. 91, a lateral horizontal passage, 16, just below the opening, 2, is connected by a pipe, 17, to a source of vacuum.

H. G. C.

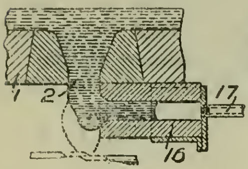


FIG. 91.

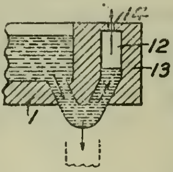
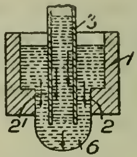


FIG 90.



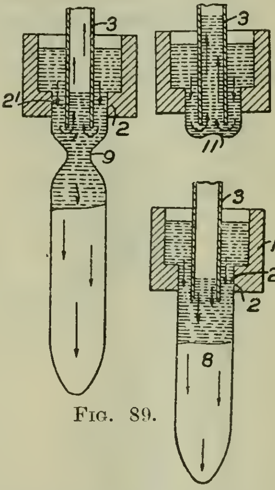


FIG. 89.

213. Grinding and Polishing Machine for Lenses.

W. S. Tanner (Brit. Pat. No. **120827**, Feb. 4th, 1918, No. 1985).—In a machine for grinding and polishing lenses, etc., a number of grinding-heads are carried on a table, *m* (Fig. 92), mounted to turn about a central rotating shaft, *b*, from which is taken the drive both of the spindle, *o*, of the grinder, or lower tool, and that of the frames, 9, carrying the work-holders, or upper tools, the arrangement being such that, while the table normally is held stationary, it can be released and stepped round to bring the grinding-heads in succession in front of the operator. Each grinding-spindle is driven from the central shaft by friction wheels, *r*, *k*, *h*, of which the wheel *k* is mounted at the end of a hand-lever, *s*, pivoted at *u*, so that it may be swung upwards or downwards to engage with parts of different radii on the wheels, *r*, *h*, and thus to vary the speed transmitted. At the lower end of the wheel *h* is a plain loose ring, *i*; when the wheel *k* is brought into engagement with this ring, the drive ceases. The spindle of the wheel *k* works in a slot in the bent end of the lever *s*, and is drawn towards one end of the slot by a spring which pulls the wheel *k* into contact with the wheels *r*, *h*. Instead of the conoidal wheels shown, flat friction discs may be mounted on the shaft and on the spindle; the intermediate wheel then stands vertically, and is moved towards and from the centre of the shaft by a yoke actuated by a screw, and the disc on the spindle is pressed down by a spring, the drive being stopped when desired by lifting the disc by means of a cam on a spindle provided with a handle. The frames, 9, for the upper tools are mounted on arms, 6, which are connected by blade springs, 7, to a boss, 5, that is set in motion by an adjust-

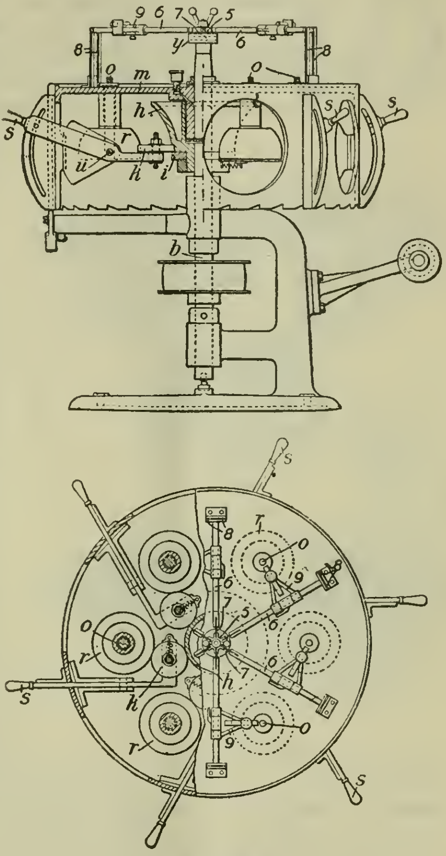


Fig. 92.

able-throw crank-pin in the disc *y* at the top of the central shaft. The frames may be turned up on the rods to allow of access to the tools. The outer ends of the arms are supported by vertical blade springs, 8, or they may work through eyes in swivelling posts.

H. G. C.

214. Grinding and Polishing Glass. Pilkington Bros. and F. E. Slocombe (Brit. Pat. No. **120697**, October 10th, 1917, No. 6125/18).—A vacuum device for holding plate glass on to a table while grinding or polishing comprises a sucker adapted to adhere to the glass attached to a piston or cup of smaller area than the sucker and working in or on a cylinder carried by the table, the spaces within the sucker and the cylinder being connected together and to an exhausting means, with the result that the unbalanced atmospheric pressure on the glass is divided in a definite proportion, part operating to press the glass on to the table, the remainder pressing the glass on to the sucker rim.

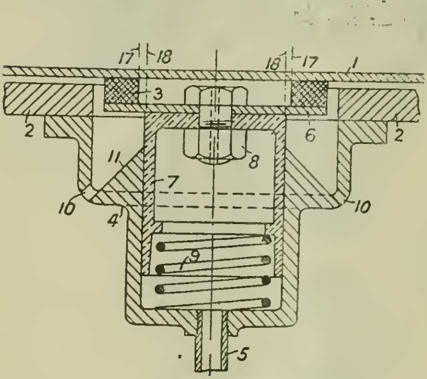


Fig. 93.

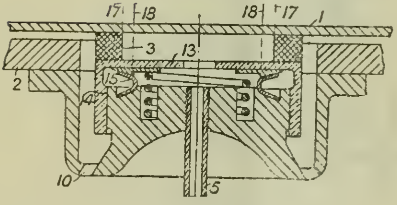


Fig. 94.

Means are provided for preventing access of abrasive material to the sliding surfaces of the piston or cup. As shown in Fig. 93, the rubber ring, 3, of the sucker is carried by a disc, 6, secured by a perforated bolt, 8, to a piston, 7, sliding in a cylinder, 4, secured to the table, 2. The piston is pressed upwards by a spring, 9, and the cylinder communicates by a pipe, 5, with an air-exhausting pump. When air is exhausted from the cylinder and sucker, the pressure between the glass plate, 1, and the sucker rim is proportional to the area between the dotted lines, 17. As the plate, 1, and the sucker and piston move inwards, the glass engages the table and the total pressure is divided between the table and the sucker rim in the proportion of the area between the lines, 18, to the annular area between the lines, 17, 18. Abrasive material is prevented from reaching the piston, 7, by the overlap of the disc, 6, and the cone or cylindrical surface, 11, by which the material is guided to apertures, 10. In the modification shown in Fig. 94 the sucker piston is replaced by a cap, 13, sliding externally on a boss, 14, secured to the table, 2. The cap is perforated and the vacuum space beneath it is enclosed by a rubber or like ring, 15. A series of suckers may be arranged on the surface of the table which may be horizontal, vertical, or inverted, and the suckers may be utilised to flatten slightly buckled plates.

H. G. C.

215. Glass Cutting or Dividing Machine. W. R. Lyttleton and Triplex Safety Glass Co. (Brit. Pat. No. **114462**, March 31st, 1917, No. 4688).—Relates to cutting glass into oval or other curved shape, and consists of a construction of machine in which the cutting edge of the tool is kept facing the direction of movement, and the holder is maintained in contact with a template by a link and spring arrangement. The figures show an apparatus in which the glass, *F* (Fig. 95), is stationary, and the tool, *L*, moves. The tool, *L*, is mounted in a bush, K^1 (Fig. 96), which is free to turn in a sleeve, J^3, carried by a link, *J*, connected by a radius-bar, *I*, which can be turned by a crank-handle, *H*. The link carries an adjustable slide, *N*, the forward end, N', of which is formed with two shoulders which bear on the edge of a fixed template, *F*, corresponding in shape with the design to be cut. A spring, *P*, keeps the shoulders against the template during the movement of the tool. The upper end of the tool engages the under-face of the template. The cutting apparatus is carried on links, *C*, *D*, pivoted to a fixed standard, *B*, and is normally kept raised by a spring, *Q*. In a modified arrangement, the glass turns with the template and the diamond-holder has no rotary movement.

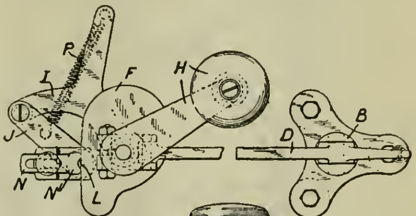


Fig. 95.

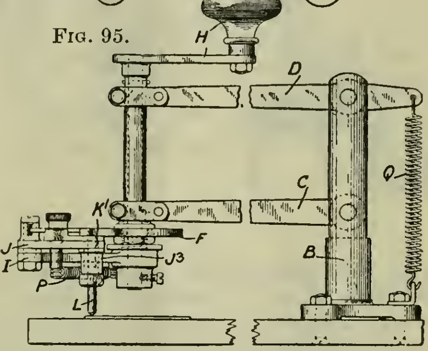


Fig. 96.

H. G. C.

216. Feeding Device for Bottle Machines. J. Forster (Brit. Pat. No. **113797**, December 14th, 1916, No. 17970).—In apparatus for feeding bottle-making machines with molten glass, and of the kind in which a gathering head or carrier sucks up the glass from a furnace or tank and is then moved to the receiving part of the machine, where the charge of glass is discharged by air pressure, the gathering-head, 3 (Fig. 97), is arranged to be rocked in the vertical plane. The tubular head, 3, is carried by an arm, 1, which is mounted on a horizontal pivot, 2, in a pedestal, 20, and fixed to or formed with a quadrant, 16, having a toothed endless rack, 15, with which the driving-wheel, 14, gears. Suitable mechanism is provided to move the wheel, 14, from one rack to the other at the ends of the oscillations of the head, 3. Links, 18, pivoted at one end, 19, below the pivot, 2, and at the other end to the head, 3, keep the head vertical during its movement. The tank, 5, which is fed by a runner, 7, from the furnace, 6, and provided with heating-means beneath its cover, 8, may be arranged to move both laterally and longitudinally so that the gathers are made from different parts of the tank. The vacuum and air valves, 12, 13, in the pipe, 11, to which the head, 3, is connected by a flexible pipe, 10, may be operated automatically by means of tappet levers, 21, 22, engaged by pins, 23, 24, situated on opposite sides of the quadrant, 16.

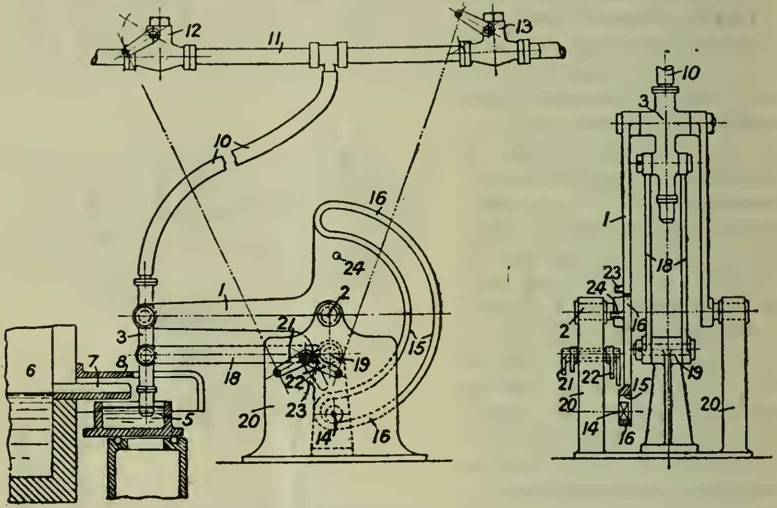


FIG. 97.

H. G. C.

I.—Glass-making Materials.

217. Drying Sand, etc. G. F. W. Hope (Brit. Pat. No. **124244**, February 20th, 1918, No. 3054).—Relates to rotary drum apparatus for drying sand, etc. The material is fed from a hopper, 2 (Fig. 98), through a shoot, 12, into a rotating perforated or open-work drum, 1, provided internally with beaters, 5 (Fig. 99), and pivoted shelves, 10. The shelves are supported by chains, 17, so that they fall back as the drum revolves. The beaters, 5, have looped ends, 6, which engage the shaft, 4, and are thus free to move to a certain extent at right angles thereto. The beaters are lifted by angle-pieces, 9, carried by the drum, and, when raised sufficiently, slip inwards and clear the angle-pieces. Material escaping through the openings in the drum is received by one or more oscillating plates, 13, actuated by a cam, 14, and heated by gases from a furnace, 16. The material passes to another plate, 15, which may also be oscillated, and is delivered to a conveyor. The drum is driven through toothed gearing, 7, 8, or otherwise. The shoot, 12, is rocked by the passage of the trays over it. An adjustable gauge may be arranged between the plates, 13, 15. H. G. C.

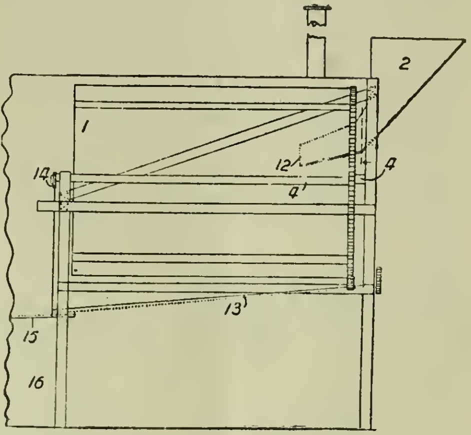


Fig. 98.

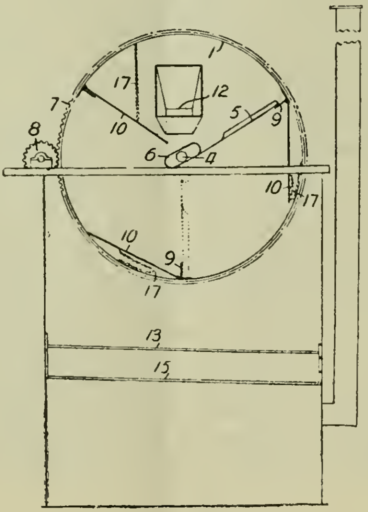


Fig. 99.

218. Potash Recovery at Cement Plants. A. W. G. Wilson (*J. Soc. Chem. Ind.*, 1919, **38**, 314T).—During the production of 350 lb. of cement, from 2 to 7 lb. of potassium salts, together with sodium and lithium salts, were carried out in the flue dust and gases. These salts were derived from the alkaline silicates usually found in the clay or shale used as raw material. In contact with lime, these silicates were decomposed at the high temperatures (maximum about 1430°), and dust and volatile salts of the alkali metals, together with carbon and sulphur dioxides, were found in the flue gases. The main potassium salt obtained was the sulphate, though the thiosulphate, sulphide, and carbonate were also found.

Nineteen cement plants were known to have installed equipment for preventing escape of flue dust, and of those one disposed of the dust as a potash fertiliser, one merely collected the dust, whilst the other seventeen were for potash recovery from the dust. The electrical precipitation installations were to be found in nine cement plants in the U.S.A., and one each in Norway, Sweden, Spain, and Japan. Six plants in the U.S.A. used five different systems of water spraying.

The various systems of recovery were described in detail and the costs of the potash recovery discussed. F. W. H.

219. Separation of Potassium and Sodium Nitrates. F. A. Freeth and H. E. Cooksedge (Brit. Pat. No. **124513**, February 25th, 1916, No. 2847).—Potassium nitrate is recovered from commercial sodium nitrate by digesting the sodium nitrate with water or wash liquors at a temperature of about 80—100°, and, if the solution is not saturated with potassium nitrate, concentrating the solution until it is so saturated, the precipitated sodium nitrate being separated and washed; the solution, saturated with potassium nitrate, is then diluted with water until the ratio of the water to the sodium nitrate is the same as that which would obtain in a solution saturated with sodium and potassium nitrates at the temperature to which the solution is to be cooled, for instance, about 20°, and the solution is then cooled to that temperature. Potassium nitrate separates, and is removed and washed. The mother liquor, and, if desired, the washings of the sodium nitrate, may be concentrated until saturated with potassium nitrate at the temperature of concentration, and then treated as before to obtain more potassium nitrate. The washings of the potassium nitrate may be concentrated until saturated with potassium nitrate at the temperature of concentration, and then cooled to obtain a further separation of potassium nitrate.

H. G. C.

220. Potassium Carbonate. S. R. Scholes, U.S.A. (Brit. Pat. No. **117755**, November 5th, 1917, No. 16157).—Minerals such as felspar are ground and mixed with a sodium or potassium compound, the carbonate, for example, in such quantity as to supply one equivalent of alkali metal oxide to each two equivalents of silica in the mineral, and the mixture is fused. The melt is poured into water and ground, and is then boiled with water and treated with carbonic acid or gases rich in carbonic acid, for instance, cement kiln gases containing potash. The alkali carbonates are then formed in solution, leaving hydrated silica, alumina, etc., as a precipitate. The solution is filtered off and evaporated; a quantity equal to that extracted from the rock is withdrawn, and the remainder is used to treat the next batch of rock. If the operation is started with sodium carbonate, all the sodium carbonate may be thus withdrawn after a number of cycles, leaving only potassium compounds for subsequent cycles. Alternatively, when sodium carbonate is used to start the operation, the solution first obtained may be concentrated so as to precipitate most of the sodium carbonate which is separated, and the potassium carbonate remaining is then used with an appropriate quantity of rock for the next cycle. H. G. C.

221. Potash Discovery in Sicily. (*J. Ind. Eng. Chem.*, 1919, **11**, 246).—It is reported that in the province of Cattanisetta, in the Island of Sicily, immense deposits of potash have been discovered, and the preliminary investigations are said to establish these as the richest in the world, making it quite unnecessary to have recourse to German supplies. C. M. M.

222. Potash from Kelp: The Experimental Plant of the United States Department of Agriculture. Preliminary Paper. J. W. TURRENTINE and PAUL S. SHOAFF (*J. Ind. Eng. Chem.*, 1919, **11**, 864).—The experimental kelp-potash plant of the United States Department of Agriculture at Summerland, California, was designed for the determination of the best methods of treating kelp for the extraction of potash salts and the simultaneous recovery of other valuable products. It was put into operation in the early autumn of 1917.

One hundred tons of raw kelp per day were subjected to a process involving drying, destructive distillation, lixiviation, evaporation, and fractional crystallisation for the preparation of high-grade potassium chloride. The by-products yielded in commercial quantities by this process consist of kelp oils, creosote, pitch, ammonia, bleaching carbons, salt, and iodine. At present the results obtained show that it will be possible to establish a new American chemical industry of considerable size and of importance and usefulness to the nation on kelp as the basic raw material.
C. M. M.

II.—Glass: Manufacture and Properties.

223. Procedures in the Manufacture of Optical Glass. W. S. Williams and C. C. Rand (*J. Amer. Cer. Soc.*, 1919, 2, 422).—The stringent requirements for optical glass were set out. The faults likely to entail rejection were inhomogeneity, colour, devitrification or cloudiness, strain due to faulty annealing, hygroscopic tendency, and insufficient strength to withstand subsequent working operations. The necessity for the use of pure materials and intimate mixing of batch ingredients were emphasised, and the following table was given showing the percentages of impurities found in various materials examined:—

	Fe_2O_3.		SO_3.		Cl.	
Material.	Max.	Min.	Max.	Min.	Max.	Min.
Barium carbonate ...	0·009	0·0005	0·12	0·0774	0·13	0·01
Barium carbonate, C.P.	0·0067	0·004	0·08	0·018	0·069	0·0124
Red lead	0·0056	0·0015	0·055	0·01	0·13	0·017
Soda-ash	0·003	0·0014	0·03	0·0049	—	—
Lime, hydrated	0·048	0·026	0·167	0·06	—	—
Potash (K_2CO_3)	0·01	0·004	0·07	0·018	0·31	0·11
Zinc oxide	0·006	0·0057	0·327	0·11	0·35	0·078
Saltpetre (KNO_3)	0·0019	0·0007	0·0016	—	0·07	0·05
Borax	0·002	0·0004	0·034	0·018	0·005	0·0034
Alumina (Al_2O_3)	0·0022	0·0022	0·15	0·15	—	—
Sand	0·02	0·0148	—	—	—	—

A single-pot furnace, fired by natural gas and compressed air, was used for the melts, and a number of working drawings of the furnace were given. The quality of pots necessary for the manufacture of optical glass was indicated, and drying and firing schedules were furnished.

Carefully selected cullet was first filled on, and then a mixture of batch and cullet at intervals of one and a-half hours until the pot was full. The amount of cullet used for the first filling was 200 lb., and for subsequent fillings from 150 to 200 lb., the melts being such as to produce about 1000 lb. of glass.

Thorough regulation of temperature during the whole of the melting and fining period was necessary, and typical time–temperature curves were given. The elimination of seeds was accomplished by the substitution of nitrates for carbonates in the batch or by "blocking" with ammonium nitrate. Stirring operations were fully described, and a diagram of the stirring machine was shown. To prevent striæ from re-forming after stirring was stopped, the metal was cooled as quickly as possible to about 700° by tilting back the pot, supporting it by a firebrick, and directing a stream of compressed air against the bottom of the pot for three hours.

Various methods of moulding were tried. In all cases the glass was first heated to the softening temperature. Following this preliminary heating, the most satisfactory method was to place the heated glass on a furnace floor covered with mineral powder, such as alumina, flint, mica, kaolin, or lime, and as the glass softened it was worked into a block to fit the iron mould of a press. On account of the lack of skilled workmen for this process, another method was adopted. The glass, on a punty, was softened in a glory hole, shaped at a bench, and sheared into the press mould.

The annealing was carefully conducted, schedules being drawn up for each kind of glass. All glasses were heated to 200° in the first four hours, to 300° in eight hours, and to 400° in twelve hours. Then, to reach the final temperature, three and a-half hours were taken, the final temperatures being as follows:—

Flint	480°
Light crown	520
Borosilicate	550
Light barium crown	610
Dense barium crown	625

The rate of cooling was 5° per hour.

In the authors' experience, the optical properties of glass did not depend entirely on chemical composition, but varied from melt to melt even when all conditions were apparently the same. Consequently, the optical constants for any particular composition could not be determined accurately by one melt. The following table was given indicating the variation of indices obtained with the same composition and other conditions apparently equal:—

Theoretical composition.	N_D.	ν
—	1·6282	36·7
SiO_2, 44·4	1·6283	36·7
PbO, 46·0	1·6268	36·7
K_2O, 4·1	1·6278	36·8
Na_2O, 3·5	1·6288	36·5
CaO, 2·0	1·6248	36·6
As_2O_3, 0·4	1·6242	37·2
—	1·6221	37·4
—	1·6285	36·6
—	1·6265	36·7

Tables were also given showing the batch composition, time of melting, type of pot used, percentage of cullet used, and optical constants for about 180 melts. F. W. H.

224. Discussion of an Article by G. W. Morey, entitled, "An Improved Method of Optical Glass Manufacture."

C. N. Fenner (*J. Amer. Cer. Soc.*, 1919, **2**, 373; see *J. Amer. Cer. Soc.*, 1919, **2**, 146; this Journal, 1919, Abs., p. 100).—A note of warning regarding the restriction of time allowed for fining in the method of manufacture suggested by Mr. Morey. The author considered that shortening the fining period was practicable only when the raw materials were free from certain impurities. Opalescent glass might be obtained when the batch materials used contained sulphates or chlorides, and, in that case, a longer period of fining was advisable. The use of potash containing more than 0·30 per cent. of SO_3 or more than 2·0 per cent. of Cl was liable to cause this trouble, and rendered it desirable to have a fining period of several hours at a high temperature. F. W. H.

225. The Development of Improved Gold Ruby Glass. H. T. Bellamy (*J. Amer. Cer. Soc.*, 1919, **2**, 313).—The work which supplied the information for this paper was undertaken in order to reproduce a ruby glass purchased in France before the war. It was necessary that the glass fulfilled the following conditions:—it must not shatter when introduced into a glass-blower's flame; it must not become discoloured when heated to a very soft condition; it should be of such a nature that small lenses can be formed from heated rods without subsequent annealing—the lenses should match an accepted standard, be of uniform colour, free from surface cracks and other visible defects, and when mounted in a brass shell should withstand impacts of 3 lb. applied at the rate of 115 per min.

A chemical analysis was made of the imported ruby glass, and the molecular formula calculated as follows:—

SiO_2	38·35
PbO	54·48
K_2O	6·17
Sb_2O_3	0·67
R_2O	0·70
Gold	Present.
B_2O_3	Not determined.

Calculated formula:—

$$\left.\begin{array}{l} 0{\cdot}791\ PbO \\ 0{\cdot}209\ K_2O \end{array}\right\} 0{\cdot}173\ R_2O_3 \left\{\begin{array}{l} 2{\cdot}05\ SiO_2 \\ 0{\cdot}0075\ Sb_2O_3 \end{array}\right.$$

The imported glass was made with potash, but owing to the scarcity of this material it was decided to substitute soda, and the glass was equally as satisfactory.

After making a few trial melts, a glass of the following formula was developed:—

Ruby No. 1.

$$\left.\begin{array}{l} 0{\cdot}583\ PbO \\ 0{\cdot}417\ Na_2O \end{array}\right\} 0{\cdot}0038\ B_2O_3 \left\{\begin{array}{l} 1{\cdot}95\ SiO_2 \\ 0{\cdot}0074\ Sb_2O_3 \end{array}\right.$$

The gold, which was not included in the formula, was prepared by dissolving 10 carat gold in aqua regia, separating the base metals, and diluting the gold chloride so that 10 c.c. contained 1 gram of metallic gold. The requisite volume of gold chloride was added to the sand of the batch and evaporated to dryness.

With this glass, the consecutive layers of a gather were frequently of different colours, changing to blue, purple, or brown under certain conditions, and the lenses appeared streaked.

A second ruby was consequently developed.

Ruby No. 2.

$$\left.\begin{array}{l} 0{\cdot}536\ PbO \\ 0{\cdot}464\ Na_2O \end{array}\right\} 0{\cdot}029\ B_2O_3 \left\{\begin{array}{l} 1{\cdot}96\ SiO_2 \\ 0{\cdot}107\ SnO_2 \end{array}\right.$$

The author claimed that the tin oxide added in sufficient quantity to a properly proportioned batch gives a ruby glass which does not become discoloured, but only exists in the colourless and ruby states; in any case, the rods and lenses made from Ruby No. 2 were always of a uniform ruby colour.

Simultaneously, attempts were made to produce an opalescent red, and the following formula was tried:—

Opalescent Red No. 1.

$$\left.\begin{array}{l}0\cdot502\ \mathrm{PbO}\\0\cdot342\ \mathrm{Na_2O}\\0\cdot156\ \mathrm{CaO}\end{array}\right\}0\cdot0154\ \mathrm{Al_2O_3}\left\{\begin{array}{ll}1\cdot46 & \mathrm{SiO_2}\\0\cdot0134 & \mathrm{Sb_2O_3}\end{array}\right.$$

Rods of this glass shattered in the glassblower's flame, and lenses shattered under the impact test mentioned above. The brittleness was attributed to cryolite, which was used as an opacifier, and it was decided to substitute tin oxide.

Opalescent Red No. 2.

$$\left.\begin{array}{l}0\cdot668\ \mathrm{PbO}\\0\cdot332\ \mathrm{Na_2O}\end{array}\right\}0\cdot0028\ \mathrm{B_2O_3}\left\{\begin{array}{ll}2\cdot17 & \mathrm{SiO_2}\\0\cdot3831 & \mathrm{SnO_2}\end{array}\right.$$

This glass melted well, was readily worked into rods, and lenses formed from the softened rods fulfilled the requirements specified above. With the tin oxide, a smaller amount of gold could be used to produce the same shade of ruby.

A red glass enamel was also produced by mixing finely powdered Ruby No. 2 with other suitable constituents. It was necessary to treble the amount of gold in order to secure sufficient intensity of colour in the thin layers used.

The fact that the glasses containing tin oxide could only exist in two colours was criticised by various writers; in particular, R. L. Frink pointed out that the statement was not compatible with the results as found by Zsigmondy and others, who stated that gold when existing in colloidal or aqueous solution may produce colours ranging from red to blue. A. M. J.

226. Batch Mixtures for Opal and Violet Opal Glass.

(*Sprechsaal*, 1906, **39**, 53).—Three batches were recommended for an opal glass to be melted in a covered pot. They are—

Sand	100 kg.	100 kg.	100 kg.
Fluorspar	22	10	18
Felspar	20	35	25
Soda	20	20	33
Potash........................	—	12	5
Red lead	20	10	6
Saltpetre	4	6	2
Cryolite	—	5	12
Calcspar	—	8	—
Arsenic	1	—	0·5

Two batches stated to produce good violet opal glasses are—

Sand	100 kg.	Sand	100 kg.
Fluorspar	12	Potash	15
Felspar	10	Lime	6
Cryolite	6	Cryolite	14
Soda	15	Borax	4
Potash	10	Red lead	10
Saltpetre	5	Copper sulphate	6
Red lead	10	Smalt	0·2
Alumina	5		
Zinc white	8		
MnO_2	8		

J. R. C.

227. Deposits on the Crowns of Glass Furnaces. W. H. Zimmer (*Sprechsaal*, 1905, **38**, 1913, 2077).—In a Siemens' pot furnace a deposit about 6 cm. thick was formed on the crown after it had been working a few weeks. The crown itself was not attacked. The deposit was a pale yellow, crystalline mass insoluble in water and mineral acids, soluble with difficulty in hydrofluoric acid. Analysis showed it to have the following percentage composition:—

SiO_2	94·62	PbO	0·14
Al_2O_3	0·33	CaO	1·93
Fe_2O_3	1·08	MgO	0·07
Na_2O	1·42	K_2O	0·51
Cl	Trace		

Neither fluorine nor sulphur was present, even in traces. It was at first thought that it was due to some of the sand used having been deposited on the crown, the excess of alkali and lead resulting from volatilisation of these constituents of the batch. Examination, however, of the structure of the layer led to the conclusion that the silica was originally amorphous, and heat had converted it into tridymite. It appeared therefore probable that volatile silica compounds were formed which, coming into contact with the roof, deposited silica thereon. None of the pots were used for fluorspar batches, so silicon fluoride was out of the question, and it was not likely that enough silicon tetrachloride would be formed to produce such a large deposit, though this would account for the trace of chlorine. The author cited a case of a similar deposit which Seger encountered in the flue of a Horn's generator. This was explained on the assumption that, as the coal used was of poor quality, silicon fluoride and chloride were formed in the generator and decomposed in the flue. This explanation was considered to hold good also for the deposit in question. Thus the remedy when such a phenomenon occurred was to change the coal used in the producer. J. R. C.

228. Decolorisers and their Effect. H. Schnurpfeil (*Sprechsaal*, 1905, **38**, 1331).—Experiments were made with a glass of the following batch composition:—

Sand	188 kilos.
Potash	28 ,,
Soda	27 ,,
Limespar	25 ,,

This batch melted in about eleven hours under the furnace conditions employed, yielding a brilliant glass. It was slightly green owing to the presence of iron in the raw materials.

Nickel oxide was found to be very uniform in its effect, but must be free from cobalt. Owing to its high melting point, it acted at the end of the melt. The normal quantity required was 2·5 grams to every 100 kilos of sand. Antimony oxide attacked the furnace, so was not recommended. Cobalt oxide was also uniform in its effect. Very little was needed, 0·5 to 0·75 gram being sufficient for 100 kilos of sand. Manganese was better suited for use with a potash glass than with soda. In the former case it gave a violet colour and in the latter purple. The objection to it was the tendency of a glass thus decolorised to be coloured by sunlight. Usually 250 to 300 grams of MnO_2 were required for 100 kilos of sand. Arsenic was more useful for removing small bubbles than for decolorising, as it volatilised at 412°. In the author's view, the uncertainty attending the use of selenium militated against its employment. The quantity required must be ascertained accurately or an uneven red coloration would result. When correctly used, it produced a very brilliant glass. An example was given of the use of selenium with the batch quoted at the beginning of the abstract.

Quantity.	Furnace.	Remarks.	Nature of result.
3 gr.	Normal.	—	Good.
3 gr.	Cold.	Adverse wind and wet coal.	Very faint green.
3½ gr.	Normal.	—	Slightly red.

Stress was laid on the fact that a hot furnace was one of the best decolorisers.
J. R. C.

229. The Theory of Making Copper Aventurine Glass.

V. Auger (*Compt. rend.*, 1907, **144**, 422).—Copper aventurine consists of a greenish, transparent mass containing innumerable small, red crystals in suspension, which impart a golden-yellow tint to the glass.

Two views are held as to the nature of these crystals. According to the first, they are of metallic copper; according to the second, of cuprous oxide or silicate. By the former theory it is difficult, according to the author, to explain how the copper enters into solution in order to crystallise out on slow cooling, as the metal is scarcely soluble at all in the fused mass.

The author studied the behaviour of cuprous phosphate when fused and then cooled, and found that when fused and cooled rapidly a colourless, transparent mass was produced, but on reheating copper separated out. Copper aventurine behaves in just the same way when treated similarly.

Since, then, copper aventurine contains a cuprous silicate which behaves as the phosphate, being stable at a red heat, but splitting up on slow cooling into metallic copper and a blue cupric silicate, but on rapid cooling remaining unchanged, this would explain the behaviour of the glass, and this view was supported by results of analysis. This theory requires that the cupric silicate be present in quantity at least equivalent to the amount of free copper, and in order to test this, the author isolated a small quantity of copper by treating the powdered glass with dilute hydrofluoric acid in the cold. After washing with water and alcohol, this isolated substance was found to possess the properties of metallic copper. Four grams of the sample furnished 0·052 gram of copper, 0·034 gram being extracted by an alcoholic solution of silver nitrate, and a further 0·018 gram being obtained by the action of dilute nitric acid. A microscopic examination of the residue showed no further trace of metallic crystals, but on treatment with hydrofluoric acid a further 0·08 gram of copper was found present as cupric silicate.

Hence the author concluded that copper aventurine consists, in the fused state, of cuprous silicate, which on slow cooling yields metallic copper and cupric silicate, the latter producing a greenish tint by its blending with the yellow of the ferric silicate in the glass. V. D.

230. Notes on the Welding of Glass. M. Léon Appert (*Bull. Soc. d'encouragement pour l'ind. nationale*, Jan.—Feb., 1919).—The author stated that it was now possible to make glasses to satisfy the conditions necessary for successful welding, either with other glasses or with metals. The conditions were:—(*a*) The glasses must have the same coefficients of thermal expansion over the range of temperature to which the finished articles are likely to be submitted. (*b*) The diathermancies, or power of transmitting heat, must be equal. (*c*) The glasses must be inert and sustain no change whatever during the heating necessary in welding.

The first condition was most important and applied to all cases, while the other two were only of secondary importance.

Since the actual determination of the coefficients of linear and cubical expansion is long and tedious, the author advocates the use of methods which aim at determining the state of tension existing between the two glasses. If the coefficients of expansion were equal this is zero, whilst it was very great if the values differed very much.

Assuming that a "compound" glass behaved as would a piece of any one of the constituent glasses alone if the union be perfect, a piece of one glass was blown into a bulb or any convenient shape and used as a standard for future comparison. Thus, let V_1 be the glass chosen as standard and V_2 be a glass to be experimented upon. Two bulbs are blown: (1) of a layer of V_1 covered with a layer of V_2, and (2) of a layer of V_2 covered with a layer of V_1, and the thickness of these bulbs is made the same as that of the standard bulb (see Figs. 100 and 101).

Although alike in appearance, these bulbs behave very differently, and if the coefficients of expansion differ very much, one will burst violently, while the other cannot be broken except by severe blows. In the first bulb the glass, V_1, forming the inner layer is the more expansible, and it creates a strain of extension in the outer layer, V_2, while in the second bulb the outer layer, V_1, is strained by compression.

In order to test this state of tension, if it exists at all, a small cut is made on the bulb, and, on tapping gently, this crack spreads regularly, cutting the bulb into two almost equal parts if the union be perfect, the bulb behaving as the standard bulb would when treated similarly (Fig. 102). If the welding is unsatisfactory, the bulb is split into more or less numerous parts, each piece having a very irregular and indented outline (Fig. 103).

The second bulb, blown in the inverse order, will break under these conditions with more or less violence, the pieces being very irregular, but with rounded edges, the cracks not being rectilinear.

Further, let the inner surface of a piece of each bulb be cut; thus, in the first bulb glass V_1 is cut, while in the second bulb glass V_2 is used, and several more or less convergent lines are made. Two cases then arise: (1) if union be perfect, each of the pieces will crack along the marks made, as will also a piece of the standard bulb if treated in like manner; (2) if union be imperfect, it will be found impossible to make the slightest scratch on the fragment of the first bulb without shattering the piece, recalling the behaviour of the thick-walled "Bologne Vases." Considering the second bulb, it will be found impossible to make the slightest scratch on V_2. Thus, if the more expansible glass be blown on the outside of a vessel, it exhibits a durability equal to that of tempered or hardened glass. By means of these tests, the order of expansion is tested.

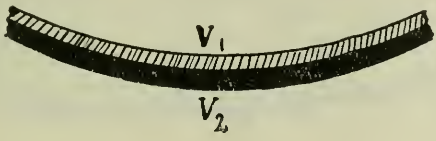


Fig. 100.

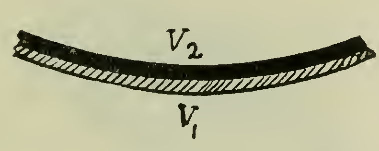


Fig. 101.

Although by welding a glass of greater expansion on to one of lesser expansion, and by a careful choice of thicknesses and arrangement of the layers a glass of very great mechanical resistance is obtainable, yet the success of the operation is not so assured as when glasses of equal expansions are used.

Little is known of the athermancy of glass. On the one hand, glasses coloured by metallic oxides are athermanous, that is, intercept and store up heat rays, and, on the other, only optical and special glasses are diathermanous, that is, able to transmit heat rays. In "doublets," where the thickness of the layers may vary considerably, the storing of heat in the coloured layer may result in a great rise in temperature, and the welding of thick coloured layers to colourless layers is not satisfactory.

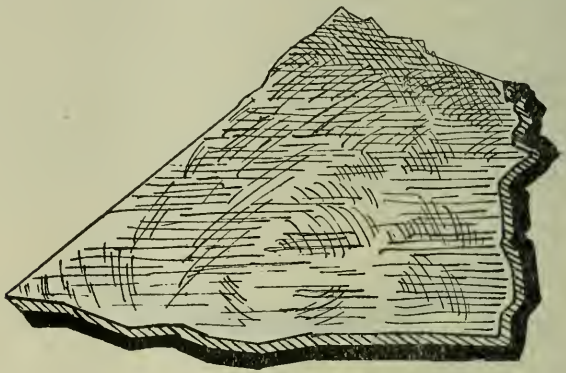


Fig. 102.

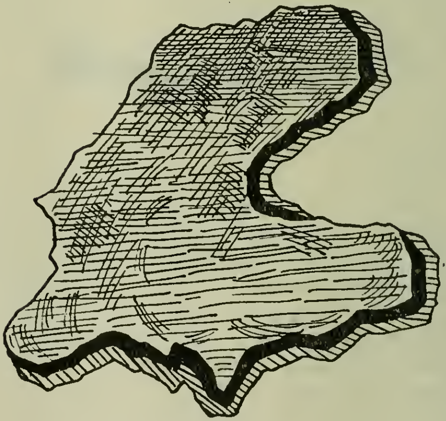


Fig. 103.

Although alum solutions absorb infra-red rays, glasses of varying alumina content have not been found to do so.

Glasses are more or less resistant to change, according to their composition, and glasses rich in bases are far from stable when heated. The stability of a glass is tested by heating it to the temperature employed in welding, when any change renders it useless. The chemical inactivity of the glass surface is tested by leaving it in contact with a sensitive liquid, for example, phenolphthalein or morphine hydrochloride.

The flame used in welding should be uniform and combustion should be complete, for oxidising or reducing conditions may affect the glass surface.

The author referred to the different methods of welding different types of glass to one another and to metals. In the welding of glass with metals, the surfaces must be well cleaned, so as to remove all traces of foreign matter, especially organic material, which, on heating, would be likely to generate bubbles of gas, and thus prevent good contact. The processes employed are of three types: (*a*) the embodiment of the metal in glass; (*b*) the deposition of metal on the glass surface; and (*c*) the deposition of glass on a metal, generally termed enamelling.

The first process is very important, being used in the manufacture of lamps of the Edison type, and of "wire-glass." The wire that is welded to the glass must possess the same coefficient of expansion as the glass, which often is of the composition of common window-glass. In the U.S.A. a special steel is used which resists oxidation and possesses a high polish even after welding.

Gold and platinum leaf will adhere to glass on heating; then a thin layer of glass fused over the whole preserves the lustre of the metal.

The second process in its true sense can only be brought about with platinum, though silver and copper can be deposited on glass by the reduction of their salts. Oxidation of the metal is prevented by covering it with a thin layer of glass. The deposition of silver and copper can also be accomplished electrolytically.

Ancient decorative enamels have been found to contain silica, potash, soda, and lead, the lead rendering them easily opaque.

A satisfactory enamel must possess the following properties:—(i) a melting point much lower than that of the metal to be enamelled; (ii) ability to attack the metal at its melting point and form a strong union; (iii) the same coefficient of thermal expansion as the metal over the range of temperature to which the articles are likely to be submitted; (iv) resistance to attack by liquids likely to be placed in the vessels.

The second condition is easily satisfied, and rather than sacrifice certain physical properties of the enamel, an intermediate glass or "flux" is used, and this has the power to attack the metal.

Gold and platinum are not readily attacked, silver is less resistant, but iron and copper are easily attacked.

When it is found necessary to alter the composition of an enamel or metal, the latter is chosen, the desired expansion being obtained by a combination of metals, as in the case of Demet, composed of one layer of nickel and two of copper.

The thermal conductivity of an enamel always differs from that of the metal, and renders cracking on sudden changes of temperature very easy, but this is remedied by coating the other side of the metal with the same mordant.

Whether applied to a cold or hot surface, enamels must be heated in a muffle to bring about fusion and form a perfect union. They should also be applied in successive layers, the thickness being very small in the case of transparent enamels to allow the play of light in them to bring out the colour, whilst on articles in common use a greater thickness is desired to give greater mechanical resistance. V. D.

231. Devitrification of Glass. N. L. Bowen (*J. Amer. Cer. Soc.*, 1919, **2**, 261).—The devitrification of glass, in the author's view, is the result of the tendency of glass to reach the stable crystalline condition, and takes place whenever the glass is maintained for a sufficiently long period of time within the range of temperature where the crystallising power is great. The author discussed crystallisation from the fundamental principles of physical chemistry, and then applied these principles to the devitrification of glass.

Definite chemical compounds almost invariably had definite melting points, and a solid crystalline substance when raised to the melting temperature usually passed promptly to the liquid condition. If the liquid was then allowed to cool and the conditions were such that equilibrium was attained, crystallisation would take place at the temperature of the melting point. It was frequently possible to lower the temperature below melting point without the incidence of crystallisation, when the liquid was said to be undercooled.

Usually only a certain amount of undercooling could be accomplished, and when this had been attained crystallisation occurred.

Certain substances might, however, be undercooled an indefinite amount, passing gradually and continuously from the state of fluent liquid through a condition of continuously increasing viscosity until, finally, a rigidity comparable with that of ordinary crystalline substances was attained, although the substance was still, from the point of view of the physical chemist, an undercooled liquid. The substance was then said to be in a vitreous condition, or simply a glass.

Compounds such as $MgSiO_3$, Al_2SiO_5. $CaSiO_3$ had a comparatively great crystallising power through a long range of undercooling, and could only be cooled to the vitreous state when the rate of cooling was very great. These silicates were poor conductors of heat, and could therefore be cooled to the glass condition only in a very small mass; they could not then be used as ordinary commercial glasses. A large number of silicates, particularly those of the alkalis, could be cooled quite slowly without crystallisation.

In mixtures the specific properties were modified. Thus, for example, the crystallisation temperature of pure $CaSiO_3$ under equilibrium conditions was 1540°, but only 1490° when mixed with 15 per cent. SiO_2. Unlike the pure compound, this mixture did not crystallise entirely at a definite temperature, but, as the temperature fell, crystallisation of $CaSiO_3$ continued, and the remaining liquid changed its composition until finally, at 1435°, when the liquid had the composition 78 per cent. $CaSiO_3$, the silica began to crystallise and the whole mass solidified, giving a mixture of $CaSiO_3$ and silica.

The effect of the addition of silica was to lower the temperature of crystallisation of $CaSiO_3$ to a temperature at which the viscosity was much greater, and therefore the crystallisation power much decreased. At the same time the silica, in virtue of its own inherent properties, made a further addition to the viscosity of the liquid. Cooling to a glass was quite readily accomplished with this mixture, though so difficult with pure $CaSiO_3$.

In cooling the mixture of $CaSiO_3$ and SiO_2, the rate must be made such that the glass did not remain long within the temperature range where the crystallisation of the $CaSiO_3$ or SiO_2 or both was great.

With mixtures of more than two components, there was, on cooling, a certain temperature at which the liquid becomes saturated with one of the components, a lower temperature at which it became saturated with a second component, and so on for all the components.

Studying the theory of devitrification in the light of the foregoing, there were three distinct danger periods during which devitrification was likely to occur. The first was during the cooling, preparatory to working, that is, during gathering or final stirring (optical glass).

When devitrification or crystallisation did occur at this comparatively high temperature, it usually took the form of the separation of large individual crystals. Devitrification of this type was furnished during the manufacture of an optical glass known as a light barium crown, when crystals formed during the final stirring. From considerations of the fluidity of the glass it was not advisable to stop the stirring at a higher temperature; hence the composition of the glass had to be altered. By determination of optical properties the crystals were identified as $BaSi_2O_5$. The melting point of pure $BaSi_2O_5$ is 1426°, whilst the temperature at which the light barium crown became just saturated with $BaSi_2O_5$ was 1100°. The glass then contained 57 per cent. $BaSi_2O_5$. A change of composition so as to reduce the $BaSi_2O_5$ about 5 per cent. (with a corresponding decrease in saturation temperature) was made, when no further trouble was experienced owing to devitrification.

The author had had submitted to him a sample of plate glass containing crystals of *wollastonite* ($CaSiO_3$) up to 4 mm. in length formed in the pot during the "hold over" immediately preceding the casting of the plate.

In a communicated discussion, W. S. Williams, of the Bureau of Standards, stated that he had not experienced devitrification of a light barium crown, but a dense barium crown exhibited

12 inches of dense, pure white opal on the surface on cooling, whilst the rest of the glass was clear.

The analyses were as follows:—

	Clear glass.	Opal glass.
SiO_2	37·88	44·67
BaO	42·36	38·02
ZnO	10·52	9·25
B_2O_3	9·31	8·46

In reply, Dr. Bowen stated that he had seen a scum formed on a barium glass. Under the microscope it was found to consist of glass with a cloud of minute crystals of silica in one of its low refracting forms, *tridymite* or *cristobalite.* Evidently Mr. Williams's scum was identical, for calculation showed that if he took 9 grams of material corresponding in composition to his "clear glass" and added 1 gram of silica, he would obtain a material of the composition of his "opal glass." Whether the formation of these crystals was a true sample of devitrification was questionable; it seemed probable they represented silica that had never completely dissolved because the melt was too slow.

The second danger period was during the cooling from its final temperature in the furnace or tank, when it was plastic, to lower temperatures at which it was rigid. During this period it was usually worked into form by blowing, drawing, casting, etc. (in the case of optical glass the metal was usually cooled in the pot itself). Under these conditions the devitrification appeared in the form of spherulites or in that of very small crystals evenly disseminated. In the author's experience the crystals were apparently in nearly all cases one of the low refracting forms of silica (*tridymite* or *cristobalite*).

Substances such as SO_3, Cl, arsenic, or fluorine seem to exert an influence in promoting this form of crystallisation. The type of barium crown glass the devitrification of which at high temperature had already been described might undergo further devitrification during the cooling stage, with separation of spherulites of $BaSi_2O_5$.

Spherulites of *wollastonite* sometimes separated from an ordinary crown glass which had an excess of lime as compared with fluxes. The final danger period for devitrification was the period during which it was reheated, whether for working into a desired form or for annealing. In this case the inter-relation of time, temperature, composition, and power of crystallisation must be carefully considered.

Shaping or moulding should be conducted at such a temperature that absolute freedom from devitrification was guaranteed.

The choice of annealing temperature was not so easily made, for at low temperatures devitrification was induced in a certain time at a certain temperature, in a shorter time at a higher temperature, and so on. A foreknowledge of both rates of devitrification and of rates of annealing for various glasses was requisite, so as to determine whether devitrification would be induced at any given temperature in a period of time which was long enough to give adequate annealing at that temperature. (A table of results for certain optical glasses was given.) There were glasses in which fine annealing and freedom from devitrification were mutually incompatible. Certain opaque (devitrified) glasses used for ornamental purposes were clear when first cooled, and became opaque only on reheating.

Frequently devitrification took place only at the free surface of a piece of glass, but the reason for this greater freedom of devitrification at the surface was unknown. A. M. J.

232. The Hardness of Glass. S. Lecrenier (*Sprechsaal*, 1905, **38**, 1665, 1705).—The author commented on the lack of a suitable method of measuring hardness, and reviewed the attempts made to supply the need, commencing with the introduction of Moh's scale. For his investigations on the hardness of glass he decided to follow Auerbach and measure the extent to which a sphere of sandstone could be pressed into a glass block without permanent deformation of the sphere or block.

Both Auerbach and the author attempted to find some relation between the chemical composition. The results obtained by the former, using fourteen glasses, the composition of which was stated, were given. An attempt was made by Auerbach to express the hardness in terms of the percentage analyses, and though not very successful in obtaining coefficients which satisfied the equation $H = a_1 w_1 + a_2 w_2 t \ . \ . \ .$, w_1, w_2 . . . being percentages of constituent oxides, derived the following values:—

Al_2O_3.	ZnO.	K_2O.	SiO_2.	BaO.	PbO.	P_2O_5.	B_2O_3.	Na_2O.	CaO.
10·1	7·1	3·9	3·32	1·95	1·45	1·32	0·75	−2·65	−6·3

These coefficients were not at all suitable for the values of hardness obtained by the author. In the experiments now described great care was taken to remove all strain from the glasses, which had well polished surfaces. The results are tabulated below. In addition to the hardness of the specimens examined, the density and the coefficients of resistance to tension and pressure were determined. The values obtained for the densities did not agree at all well with those calculated from Winkelmann and Schott's linear coefficients (see p. 176). The author concluded that the influence of the chemical constitution of the glass on the hardness thereof can thus be summarised:—(1) Soda glasses are, as a rule, harder than potash glasses containing an equal volume of silica. (2) With the pure lime-soda glasses, the hardness increases with the increase of lime and decrease of soda. (3) Boric acid imparts great hardness to glass. (4) The addition of soda and lime to lead glasses increases the hardness.

No. of Glass.	Percentage composition.									Density.	Coefficient of		
	SiO_2.	Na_2O.	K_2O.	CaO.	BaO.	PbO.	Al_2O_3 and Fe_2O_3.	As_2O_5.	B_2O_3.		Resistance to tension.	Resistance to pressure.	Hardness.
1	55·20	—	9·92	—	—	34·81	0·25	Trace	—	3·227	5·93	85·34	265
2	49·17	—	9·39	—	—	41·17	0·25	Trace	—	3·342	5·55	80·96	262
3	58·35	7·87	3·91	—	—	29·42	0·30	0·15	—	3·006	6·18	86·68	233
4	61·74	7·40	1·38	3·73	—	25·00	0·60	0·15	—	2·971	7·08	89·65	202
5	61·00	11·24	—	—	26·91	—	0·60	0·15	—	2·876	7·06	77·35	231
6	71·66	13·85	—	11·48	—	2·41	0·50	0·10	—	2·541	9·08	91·66	133
7	67·91	—	20·52	10·82	—	—	0·60	0·15	—	2·497	9·37	87·45	243
8	72·04	17·02	—	10·19	—	—	0·60	0·15	—	2·521	8·88	91·73	134
9	73·08	15·84	—	10·33	—	—	0·60	0·15	—	2·504	8·98	93·00	141
10	72·19	15·62	—	11·55	—	—	0·50	0·14	—	2·547	9·18	92·05	130
11	73·26	14·43	—	11·71	—	—	0·45	0·15	—	2·513	9·24	93·34	131
12	68·43	15·83	3·40	8·03	—	—	0·65	0·15	2·51	2·503	8·18	89·54	226

J. R. C.

233. The Determination of Young's Modulus (Adiabatic) for Glass. C. A. Bell (*Phil. Mag.*, 1905, **9**, 413).—The acoustical method was adopted, and the error due to the lack of uniformity in the diameters of the rods available was eliminated by applying an empirical correction. The number of vibrations per second executed by the rod when emitting its characteristic note was obtained by observation of the beats produced when a steel rod of nearly equal and known pitch was caused to vibrate simultaneously. The following results were obtained:—

Glass.	Density.	E at 0°.
Soft German *a*	2·508	6·95 × 10″ dynes/sq. cm.
,, ,, *b*	2·507	6·91 × 10″ ,,
,, ,, *c*	2·488	6·91 × 10″ ,,
Bohemian glass	2·394	6·38 × 10″ ,,
Gauge-tube...........................	2·525	7·36 × 10″ ,,
Soft Jena	2·499	7·16 × 10″ ,,
Flint glass *a*	3·164	5·30 × 10″ ,,
,, ,, *b*	3·136	5·39 × 10″ ,,

In the case of the soft German glass *a* there was a diminution in E of 1·12 per cent. from 5° to 100°, but flint glass *a* showed no change in this range of temperature. If the rods could not be obtained exactly uniform in diameter, uniform tapering was preferable to small, irregular variations.

In an appendix to the paper, C. Chree showed that the empirical correction applied had a theoretical explanation. J. R. C.

III.—Lamp-worked and General Scientific Apparatus.

234. A Simple Weighing Burette. D. W. MacArdle (*J. Ind. Eng. Chem.*, 1919, **11**, 670).—In order to avoid certain disadvantages in the use of ordinary burettes, such as inaccuracy of bore, temperature variation, drainage, and difficulty of reading accurately, a simple form of weighing burette could be used, thus obviating all corrections and allowing nearly as rapid work as the ordinary method with a degree of accuracy only limited by the sensitiveness of the end-point.

The author's apparatus consists of a glass stopcock and a bent capillary tube passed through a rubber stopper fitted into the neck of a conical flask which is nearly filled with standard solution. The stopcock is closed, and the flask turned up so that the capillary is inverted over the titrating vessel, and the heat of the hand is made to force the solution into the capillary. Then, when the stopcock is opened, the solution will flow out freely, and there is no danger of loss through the stopcock. Near the end-point the cock may be closed and the solution forced out in drops by the heat of the hand. S. E.

235. A New Form of Distilling Tube. J. S. McHargue (*J. Ind. Eng. Chem.*, 1919, **11**, 670).—The author's form of distilling bulb is shown in Fig. 104. The stem of the T that connects with the distilling flask is of sufficient size to allow the steam to pass into the distilling bulb and the condensed liquid to flow back into the flask without the latter being caught in a column and held in the tube by the escaping steam. The two small holes in the stem of the T within the bulb allow condensed water to return to the flask as fast as formed. The arms of the T prevent any bubbles of liquid being thrown forward into the condensing tube. Steam flowing out of the two ends of the T keeps the bulb at a uniform temperature, thus lessening condensation in the bulb and hastening distillation. S. E.

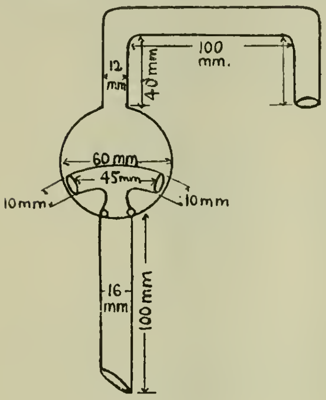


Fig. 104.

236. Blowpipe Burners. J. Keith and G. Keith (Brit. Pat. No. **117101**, May 29th, 1917, No. 7661).—In a method of producing a high-temperature flame, more particularly for glass working, the combustible mixture is preheated whilst flowing through a straight passage with a smooth surface and of such form and dimensions that it is delivered in a non-turbulent condition. The preheating may be effected by a burner supplied with a portion of the combustible mixture or otherwise, or by electrical or other means. In the form shown in Fig. 105, air and gas supplied through *B* and *C* are mixed in a body, *D*, and heated in long, narrow outlet tubes, *E*, which may be of heat-resisting alloy, by annular burners, *H*, surrounding the tubes and supplied with a portion of the mixture. Regulating screws, *G*, control the supplies to the burners, *H*, and the tubes, *E*, are provided with enlarged outlets in heads, *F*, screwed in a plate, *K*, which prevent combustion products from the burners, *H*, reaching the main burner

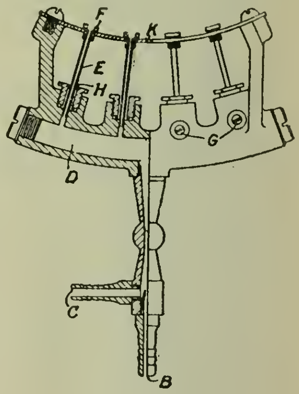


Fig. 105

flames. The tubes, *E*, may be bent to secure a fine adjustment of the position of the flame. Fig. 106 shows a unit adapted to be fitted into any form of burner. The preheating burner comprises a bush, *J*, extended to form a lantern carrying a disk, *L*, which replaces the plate, *K* (Fig. 105). In a modification, the preheating burner is a perforated tube parallel to the heated tube, and the latter is composed mainly of refractory material or is enclosed in a refractory tube. The heated tube may be $1\frac{1}{4}$ in. long and 3/64 to 1/16 in. bore.

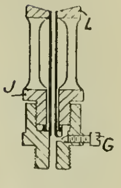


FIG. 106.

H. G. C.

IV.—Decorated Glass.

237. Platinising Pottery, etc. F. J. KETTEL, A. GASCH, and T. A. DEAN (Brit. Pat. No. **117432**, May 13th, 1918, No. 8003).—The article is covered with a solution or emulsion consisting of platinum chloride, glycerol, and phenylhydrazine, heated to 850—900° to reduce the platinum to the metallic state, and subsequently cooled gradually under ordinary atmospheric conditions. The ingredients are used substantially in the proportions of 3 grams of platinum chloride to 12 cubic centimetres of glycerol and 7 drops of phenylhydrazine. In preparing the solution or emulsion, the platinum chloride is dissolved in the least possible quantity of water, the glycerol is added, and the mixture is heated on a water-bath until it reaches the temperature of boiling water, at which it is maintained for one and a-half hours; the phenylhydrazine is then added slowly drop by drop, and the mixture stirred. Heating is continued until frothing ceases, that is, in about three hours, or the liquid may be poured away from the froth. H. G. C.

V.—Optics and Optical Instruments.

238. Deposits on Glass Surfaces in Instruments. L. C. MARTIN and (MRS.) C. H. GRIFFITHS (*Trans. Optical Soc.*, 1919, **20**, 135).—In general, films were most likely to form on surfaces enclosing the smaller spaces in an instrument. In binoculars, deposits were most frequent on the graticules, and no deposit had been found on the object-glass. The authors traced the stages in the formation of a film, it being assumed that the agents contributing to the formation were grease on the lenses, dust nuclei, water vapour, grease vapour from the lubricants, and heat. The effects of these agents were separately investigated. To remove traces of grease from the lenses, two methods of cleaning were employed, one of which was complicated (*A*) and the other (*B*) consisted of cleaning the surface with methylated spirits and wiping with silk. This latter method was found to be as efficient as the former. If the lenses were boiled in distilled water prior to cleaning, they showed a greater resistance to attack by moisture. Neither moisture nor the presence of lubricants produced a globular deposit, though the former caused disintegration of the surface; but when both these agents were present, such a deposit was observed. The presence of residual vapour of the solution in which the metallic parts had been pickled had a decided action in forming globular deposits.

The nature of the glass had a great influence, and the following table was given. The glasses were heated to 34° in an oven and allowed to cool once during each day.

Glass.	Method of cleaning.	12 days in oven.	35 days in oven.
Crown	A	Definite disintegration.	Considerable uneven disintegration.
,, ...	B	Little effect.	Some disintegration.
Baryta crown...	A	Minute pits in surface.	Action continued.
Heavy flint...........	A	,,	,,
Optical plate	B	Surface beginning to disintegrate.	,,
,, ...	B	Little effect.	Definite disintegration.
Barium light flint ...	B	Surface covered with pits	Action continued.
,, ,, ...	B	,, (pits smaller).	,,
,, ,, ...	B	Some disintegration.	,,
,, ,, ...	B	Fewer pits, but larger and more irregular.	,,

In general, the surfaces were fixed at the ends of a brass tube 1 cm. long, but in the second and fourth tests with B.L.F., the tubes were 0·5 and 4·0 cm. long respectively. The order in which the glasses could be arranged in view of their tendency to disintegrate under the action of warmth showed no agreement with Kohlrausch's order of solubility of similar glasses, nor with the order in which they were placed by an autoclave test. J. R. C.

239. The Possible Disturbance of a Range Finder by Atmospheric Refraction due to the Motion of the Ship.

Rayleigh, Lord (*Trans. Optical Soc.*, 1919, **20**, 125).—A mathematical treatment of the subject, the conclusion arrived at being that the error due to refraction was so small as to be negligible. This view was controverted by T. Y. Baker in the discussion following the paper. It was asserted that the magnitude of the variation calculated was greater than the probable observational error.

J. R. C.

VI.—Illumination and Illuminating Ware.

240. Thorium Salts. LINDSAY LIGHT CO., U.S.A. (Brit. Pat. No. **117438**. November 26th, 1917, No. 17468).—Thorium pyrophosphate.—Monazite sand is heated with strong sulphuric acid, a temperature of 175° being mentioned, to convert the thorium and rare earths into soluble form, and the heating is then raised to 250—300° until the thorium alone has become insoluble. The mass is then cooled and stirred with water, and the insoluble thorium pyrophosphate in crystalline form is filtered off, and may be further treated to obtain pure thorium compounds. Pure thorium pyrophosphate in this form may be made by heating thorium sulphate and phosphoric acid at 280°. H. G. C.

241. The Reduction of Tungstic Oxide. C. W. DAVIS (*J. Ind. Eng. Chem.*, 1919, **11**, 201).—Several industrial concerns at the present time produce powdered metallic tungsten for use in the manufacture of alloys. Although extensive, the available literature on the reduction of tungstic oxide to the metal failed to give definite information concerning the conditions involved. Hence the following work was undertaken by the author to supplement existing data.

The tungstic oxide used for reduction must be pure, dry, in a state of fine division, and should be thoroughly mixed with carbon. A blue or purple oxide was obtained at 650—850°, a chocolate-coloured material at 900—1050°, and at temperatures above 1050° grey, powdered metallic tungsten resulted.

As the tungsten was easily oxidised, the reduced material must be cooled in a reducing atmosphere. Excess carbon could be partially removed by washing, and the ratio of tungstic oxide to carbon varied from 10 : 1 to 10 : 1·6, depending on the process used, the temperature of reduction, and the time involved.

Fireclay crucibles or iron tubes gave satisfactory reduction with a product of more than 98 per cent. of tungsten, but under the conditions of the test some oxides were formed at the portions nearest the crucible cover and the ends of the tube. It was found that fireclay was not attacked by the change at the temperatures used, but that iron tubes suffered considerable oxidation on the outside.

To obtain tungsten powder free from oxides, a continuous process could be arranged, the time for reduction of small samples at 1100° being less than one hour. The temperature of reduction with hydrogen at ordinary pressures was much the same as with carbon, a yield of more than 98 per cent. of tungsten being realised. C. M. M.

VII. Fuels, Refractories, and Furnaces.

242. Problems in the Utilisation of Fuels. R. F. Bacon and W. A. Hamor (*J. Soc. Chem. Ind.*, 1919, **38**, 161T).—Some of the most important engineering problems in the utilisation of fuels were discussed. The last twenty years had seen improvements in the development of water power, in the concentration of the production of power from fuel in central stations, where the most economical methods could be used, and in the distribution of power electrically. There remained, however, a great deal to be done in the direction of replacement of inefficient and isolated power plants of various types with electric power, and from the point of fuel conservation, the largest field open at present was on the railways. The fuel supply was still abundant, and manufacturers had found it a more convenient policy to use high-grade rather than low-grade fuels. However, the supply of high-grade fuels, such as anthracite and coking coal, might soon be exhausted, possibly during this century, and consequently the conservation of all classes of fuel became increasingly necessary. The reasons for lack of development and utilisation of low-grade fuels were the cheapness with which the high-grade fuels could, in the past, be mined and transported to the markets, and the need of basic experimental and development work which was required in order to utilise the full thermal efficiencies of the low-grade fuels.

Low-grade coal and lignite could probably be utilised to better advantage in the pulverised form. In this form it required 25 to 30 per cent. of excess air, whereas in lump form, burned in "hand-fired" furnaces, it usually required 100 per cent. of excess air. The resulting temperature of the fire was, of course, a limiting factor. Bearing on this problem were other factors, such as the construction of the furnace, the proportion of heat radiated directly to the tubes, and the fusibility of the ash. Where the fuel was rich in combined nitrogen, the by-product gas producer became of value for large installations. The utilisation of waste from coal-washers was discussed at length, and the authors considered that the oil-flotation process for the recovery of the coal in most low-grade fuels would be a means of combating fuel problems of the future. Another problem which was arising was the effective development of the shale-oil industry, owing to the necessity for finding suitable substitutes for petroleum products. The various aspects of the possible development of the industry in America were considered in detail.

Engineering problems were extensive, and included the many difficulties encountered in securing perfect combustion, such as furnace volumes, rates of combustion, loss due to clinkering, scale, flue dust, etc. With pulverised coal there were the problems of crushing and drying, explosibility and storage, injection into the fire-box and erosion of the refractories, and the relative value on a heat and cost basis of pulverised coal, fuel oil, and producer gas.

The smoke evil led consideration in three directions, namely, the wider extension of the use of gaseous and powdered fuels, the adoption of electricity as a motive power, and the manufacturing of some form of semi-carbonised coal as a domestic fuel at a price which would not exceed that of raw coal.

The use of gaseous fuel from producers raised the following problems:—

(1) In the case of fixed type producers, the troubles arising from clinkering, incomplete burning of the coal, and air-holes and pressure; (2) the most economical size and shape of producers for gas to be used for heating purposes; (3) economical use of the tar by-product; (4) automatic, separate control of steam and air blasts; and (5) practical automatic check and regulation to maintain a regular quality of producer gas.

With fuel oil there were the problems of explosibility, storage, burning for perfect combustion, and action on furnace refractories.

In the refractories industry, the most important problems arose in the development of the necessary heat, and might be enumerated as follows:—

(1) Regular and even heating in the kilns; (2) effective and economic conduction of gas from producers to kilns without great loss of heat from the gas; (3) in the use of pulverised fuel, the prevention of deposition of ash dust, and development of a feeding arrangement giving combustion even at low temperatures; (4) maintenance of a good draught; and (5) avoidance of defects due to clinkering, *e.g.*, loss of temperature in kilns owing to inrush of cold air during the cleaning of fire-boxes.

The effective use of the heat developed then depended on decreasing radiation, stack, and kiln losses.

The glass industry required a cheap and continuous supply of fuel. Coal was, from the economic point of view, the most suitable fuel; fuel oil was too expensive, whilst the use of electricity in glass-making was exceedingly problematic, both from the engineering and the economic sides. Direct burning of coal in pot furnaces was inefficient, and was not applicable to tank furnaces. Improvements in producer design and the extension of the use of lower grades of fuel would be of benefit. Pulverised coal, though perhaps applicable to pot furnaces and certain types of lehrs and kilns, had not, so far, been successful for glass melting owing to the choking of flues and contamination of the glass by ash, etc. If it was used, some gaseous fuel would be necessary for "glory holes," etc.

Heat economy was one of the most important problems in the glass industry. In the case of a plate-glass furnace, only 17 per cent. of the total heat supplied was required to melt the glass, whilst 56 per cent. was lost through radiation, conduction, and in the flue gases. Many improvements were necessary in the standardisation of furnaces, arrangements of ports and baffles, regulation of air supply and gas pressure, and in the efficient construction of regenerators. As regarded furnaces for closed pots, in particular, heating of the pots evenly on all sides would reduce the heat loss. In lehrs there was need for more accurate regulation of temperature and a greater uniformity of heating in order to avoid breakage due to improper annealing and the necessity, in many cases, of a second annealing.

The fuel problems in the iron and steel industry were also dealt with. F. W. H.

243. Refractories. J. W. Mellor (*J. Soc. Chem. Ind.*, 1919, **38**, 180R).—The first effects of heat on clay were the removal of hygroscopic moisture and the dehydration of the colloidal silicic acid; at 500°, the clay was decomposed into free silica, free alumina, and water; about 800°, the alumina began to polymerise; above 1000°, *sillimanite*, Al_2O_3,SiO_2, was formed; at 1500°, the clay sintered to a stone-like mass; at 1650°, the clay softened, and at 1700° formed a brown or grey, viscid liquid.

About 500°, clay goods, during firing, absorbed heat without rise of temperature; at about 900° they became hotter than the kiln, and afterwards cooled to the kiln temperature. Clay expanded during dehydration and then contracted when the temperature rose above 600°, due to vitrification and the change of the products of decomposition to a mixture with a higher specific gravity. The specific gravity of alumina increased on heating from about 2·8 at 600° to about 3·9 at 1200°, corresponding with a contraction of nearly 30 per cent. This contraction, under ordinary firing conditions, was slow and took a long time for completion. Hence serious difficulties arose through subsequent contraction, and alumina or bauxite bricks were condemned. The author considered that these bricks had not had a fair trial. Ferric oxide, chromic oxide, and magnesia underwent analogous changes, but in a less degree, whilst with zirconia the changes were even more pronounced than with alumina.

Tests on the penetration of firebricks by dust showed that dusts consisting of oxide of iron, copper, or zinc penetrated the refractory as vapours, owing to their volatilisation at comparatively low temperatures in a reducing atmosphere. Ferruginous dusts in reducing atmospheres caused rapid slagging. Salt vapour from coal also produced a very fusible slag with silica and fireclay refractories. The best resistance to this action was given by bricks in which the ratio of alumina to silica molecules was less than 1 to 3·5. F. W. H.

244. Refractory Substances. G. W. Mottram (Brit. Pat. No. **123116**, November 7th, 1917, No. 16229).—Refractory bricks and the like are made by first dry-grinding the base material and saturating it with water, then wet-grinding the binder or flux to the consistency of a slip varying in fineness from 30—200 meshes to the linear inch with 1—4 times its weight of the base, and mixing the product with the remainder of the saturated base material. After the mixture has been allowed to stiffen and mature and excess of water is removed, it is pressed, dried, and burnt at a sintering temperature. As base material, silica, fireclay, and other old or new refractory material may be employed ground to a fineness of 8—40 meshes to the linear inch, and the clay binding material may be made more plastic by the addition of peat-water or the slime deposited from the effluent from sewage purification or the refuse liquid from tanneries. Lime or other basic oxide or iron oxide or salts to the extent of 1·5 to 4 per cent. may also be added with or without 5 to 15 per cent. of fireclay.

H. G. C.

245. A Study of some Light-weight Clay Refractories.

M. F. Beecher (*J. Amer. Cer. Soc.*, 1919, **2**, 336).—The author described a study on bricks of twelve different compositions, namely:

No.	Refractory clay.	Kaolin.	Regular. grog.	Kaolin grog.	Sawdust.
1	19	38	24	—	19
2	10	30	$13\frac{1}{3}$	—	$46\frac{2}{3}$
3	50	10	—	10	30
4	50	10	10	—	30
5	50	10	20	—	20
6	50	20	—	—	30
7	$25\frac{1}{3}$	$24\frac{2}{3}$	—	—	50
8	Norton special clay brick.				
9	A good quality silicious clay brick.				
10	A flint-clay brick (Pennsylvania).				
11	A flint-clay brick (Missouri).				
12	A flint-clay brick (Kentucky).				

The sawdust in these bricks contained no hard woods. It had a weight of 14 lb. per cubic foot when shaken down slightly, and was sized to pass an 8-mesh screen.

The major results of the study are summed up in the following table:—

No.	Weight.		Load test		Resistance to spalling.		Cone of fusion.	Thermal insulation.
	Rank.	Standard $2\frac{1}{2}'' \times 4\frac{1}{2}'' \times 9''$.	Rank.	Deformation. Per cent.	Rank.	Behaviour.		Rank.
1	6	5·51	4	2·66	10	fair	31—32	10
2	2	4·01	9	10·57	12	poor	31—32	3
3	4	5·43	12	Shear	5	good	31—32	5
4	5	5·50	6	5·54	9	fair	31—32	6
5	7	5·84	3	2·37	1	good	31—32	2
6	3	5·35	5	4·56	8	fair	32	4
7	1	3·93	11	23·80	11	poor	32	8
8	9	6·76	2	2·19	2	good	32	11
9	8	6·58	1	1·33	6	fair	29—30	9
10	10	6·87	7	7·06	7	fair	32	7
11	12	7·92	8	8·43	4	good	31—32	12
12	11	7·43	10	18·40	3	good	—	1

The results show that, except for Nos. 2 and 7, the load-carrying capacities of light-weight bricks (made with a percentage of sawdust) compare very favourably with the standard full-weight bricks.

In resistance to spalling, the light-weight bricks again show up very well. In thermal insulation they are practically equal to or superior to all the commercial brands except No. 12. Sawdust additions (to relatively open-burning clay mixtures) appear to increase the porosity by an amount equal to the actual volume of the addition.

The author drew a number of valuable conclusions concerning sawdust mixtures with fireclay, and several writers in communicated discussions pointed out that there is much scope for the development of light-weight refractories. A. M. J.

246. The Volatilisation of Iron from Optical Glass Pots by Chlorine at High Temperatures. J. C. Hostetter, H. S. Roberts, and J. B. Ferguson (*J. Amer. Cer. Soc.*, 1919, **2**, 356).—Chlorides and chlorine have previously been used to volatilise iron; for example, (1) Bole and Howe have used various chlorides to volatilise iron from enamels (*Trans. Amer. Cer. Soc.*, 1915, **17**, 125); (2) sand has been purified by igniting with 2·5 per cent. of sodium chloride (J. G. A. Rhodin, Brit. Pat. No. 8495, 1914); (3) chlorine at high temperature has been used to purify zirconia from iron (A. J. Phillips, *J. Amer. Cer. Soc.*, 1918, **1**, 791). In order to test if chlorine could be used to free glass pots from iron, experiments were first conducted on a laboratory scale to determine the best conditions.

Portions of previously burned pot-shell, held in a porcelain or alundum boat, were placed in a silica glass (or, at higher temperatures, a porcelain) tube, through which a stream of chlorine was forced. The tube was heated in an electric furnace, the temperature of which was measured by a platinum platinum–rhodium thermocouple. The first experiments showed that chlorine at 800° would remove some portion of the iron, but that better results were obtained at higher temperatures.

The details of several runs under different conditions are shown in the following table:—

Minutes to reach max. temp.	Max. temp.	Minutes held at max. temp.	Per cent. of Fe_2O_3 in pot.		Per cent. of Fe_2O_3 removed by Cl.
			Initial.	Final.	
—	1100°	120	2·19	1·03	53·0
155	1214	195	2·19	0·78	64·3
—	1225	105	2·19	1·20	45·2
185	1365	125	2·19	0·49	77·6

The results show that the chlorine treatment should be conducted at the highest attainable temperature, and should continue for at least two hours. The treated pot samples after these runs were nearly white in colour with occasional yellow spots. The colour was uniform throughout, showing that the gas penetrated to the centre.

Some pieces of ordinary red brick placed in the boat along with the pot-shell were beautifully white after treatment.

The effect of moisture and hydrochloric acid vapour with the chlorine was tried; some results are shown in the following table:—

Chlorine.	Time at max. temp.	Temp.	Iron content of pot. Initial.	Iron content of pot. Final.	Iron removed, per cent.
Dry	30 min.	1265°	1·94	0·74	61·8
Bubbled through water at 69°	30 min.	1265	1·94	0·88	54·7
Bubbled through conc. HCl at 17°	30 min.	1265	1·94	0·84	56·7

There is, therefore, no advantage to be gained by the use of moisture or hydrochloric acid vapour along with the chlorine.

Large-scale experiments were next tried at the glass works of the Bausch and Lomb Optical Co. The equipment consisted of a cylinder of liquefied chlorine, to which was connected a wash-bottle containing concentrated sulphuric acid to show the rate of flow of the gas, whilst a rubber tube connected the wash-bottle to a 15 mm. fused silica glass tube about 200 cm. long, which served to carry the gas down into the pot. Fig. 107.)

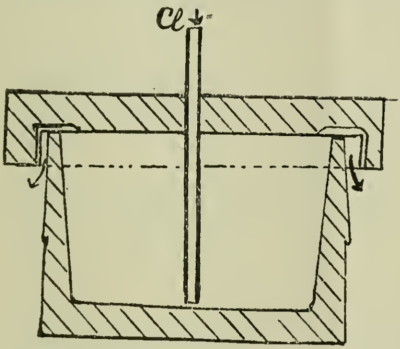


FIG. 107.—*Diagram illustrating the most effective method of introducing the chlorine and covering the pot.*

Some of the pots were treated in a recuperative furnace, others in pot arches, and one in a regenerative furnace.

In all cases the pots appear to have been of the open type. It was found best to introduce the chlorine stream so that it first impinged on the bottom of the pot (where the greatest corrosion takes place during melting), and also to control the direction of the effluent gas so that the precipitation of the ferric oxide formed by the interaction of the ferric chloride with the furnace gases would not occur within the pot.

Generally, it was found that glass made in treated pots contained less iron than glass made in untreated pots. At the same time there was evidence that the removal of iron made the pots more porous and more readily attacked by the melted batch, and therefore a greater percentage of iron was found in the glass in some cases.

The physical condition of the pot played an all-important *rôle* in resistance to pot corrosion. If a dense surface has been made on the interior of the pot, and this has been thoroughly vitrified in the arching and burning processes, the pot becomes exceedingly resistant to the action of the batch. It is possible, therefore, that if after chlorination the pots had been burnt for several hours at a higher temperature, better results would have been obtained.

The experiments were regrettably discontinued owing to the imperative demand for the maximum production of glass.

A. M. J.

247. The Comparative Value of Kneading and Pugging in the Preparation of Porcelain Bodies. L. E. Barringer and Chester Treischel (*J. Amer. Cer. Soc.*, 1919, **2**, 306).—In the authors' opinion, the pug mill is an excellent mixer and works rapidly, but tends to leave laminations where the knives and augers pass through the putty-like mass. The rolling or kneading table does not mix as well as a pug mill, but should leave the mass more free from imperfections.

The authors measured the air content of the product obtained from different machines, using Spurrier's method (*J. Amer. Cer. Soc.*, 1918, **1**, 710; this Journal, 1919, Abs. No. 174, p. 117), and it was ascertained that the kneading table is a more efficient air remover than the pug mill.

In a communicated discussion, C. E. Jackson, Warwick China Company, Wheeling, W. Va., stated that clay after it has been on a kneading machine is better in all respects than clay that is hand wedged.

The kneading machine also strengthened a weak body and produced a clay which worked more smoothly. Clay prepared by the kneading machine lent itself to the production of extremely delicate work. From the commercial point of view a pug mill has about six times the output of a kneading machine.

A. M. J.

248. Silica Bricks and their Manufacture. L. Dauphin (*Bull. Soc. de l'Ind. Min.*, 1918, **13**, 137; from *J. Soc. Chem. Ind.*, 1919, **38**, 136a).—The properties of typical silica bricks were described, and the effect of the presence of added ferric oxide, alumina, and lime on the refractoriness was discussed. Suggestions were made regarding the selection of raw materials and making and firing the best type of silica bricks. The following results of the tests on various bricks were quoted:—

Source.		Refractoriness.	True sp. gr.	Porosity. Per cent.	Composition.					Refractoriness after addition of 6 per cent. of Fe_2O_3.
					SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	
British bricks.	B.W.	1725°	2·44	24	94·3	1·40	1·66	2·30	—	—
	B.A.Y.D. ...	1733	2·36	28	95·0	0·87	2·03	2·00	—	—
	B.S.Y.D. ...	1710	2·33	26	95·0	1·17	1·33	2·20	—	—
	B.F.P.	1735	2·43	32	95·6	0·68	2·22	1·30	—	—
	B.B............	1725	2·53	28	93·9	0·86	1·84	3·0	—	—
German.	Zurbig	1728	2·30	23	95·1	1·53	0·97	2·0	—	—
	Stella	1730	2·47	20	95·9	0·41	1·87	1·7	—	—
French.	Loire	1725	2·34	31	95·48	1·86		1·78	traces	1715°
	,, ...	1725	2·56	28	96·46	1·18		2·06	0·27	1700
	S.A.M.	1715	2·35	27	93·82	1·12	2·54	1·78	—	—
	C.F.D.	1750	2·35	17	96·15	0·37	1·24	1·75	0·18	1735
American " Star "		1730	2·31	30	97·8	0·9	0·85	0·10	0·15	1710

F. W. H.

249. The Progress of Vitrification and Solution in some Porcelain Mixtures. A. S. WATTS (*J. Amer. Cer. Soc.*, 1919, **2**, 400).—The author states that the industrial application of porcelain requires three questions to be answered:—(1) How may *sillimanite* be developed in a porcelain so that the highest grade of product will result? (2) To what extent can *sillimanite* be developed in a porcelain without the loss of any desirable physical property? (3) To what extent may the solution of quartz be carried to the benefit of the porcelain?

To study the progress of *sillimanite* development and quartz solution, a body was prepared containing 33 per cent. Canadian felspar, 17 per cent. flint, 25 per cent. American china clay, and 25 per cent. American ball clay. Three portions were taken, one fired to cone 9, one to cone 11, and one to cone 13. Microphotographs of these specimens were shown. It appears that the development of *sillimanite* starts in the felspar grains and progresses with fusion. The matrix of fused felspar saturated with clay substance and quartz permeates the mass.

The composition of the clay body was altered in order to determine the influence of the degree of viscosity of the solvent upon the *sillimanite* development. The introduction of calcium flux did not apparently add to the *sillimanite* development, although it undoubtedly increased the solution of the quartz grains at any given temperature. The substitution of soda–felspar for potash–felspar was accompanied by increase in size of the *sillimanite* crystals, but the amount of *sillimanite* did not apparently increase. The preliminary fusion of the felspar and calcium flux before incorporation in the body increased the fluxing action and tended to increase the size of the *sillimanite* crystals developed. It also aided the solution of the quartz grains, but the amount of *sillimanite* was not materially increased.

A study of natural rocks showed that those containing *sillimanite* are high in alumina and alkali content. The presence of alkaline earths is unfavourable to *sillimanite* development.

A. M. J.

250. The Effect of Time and Temperature on the Microstructure of Porcelain. A. B. PECK (*J. Amer. Cer. Soc.*, 1919, **2**, 175).—Petrographic microscopic examination showed that quite dissimilar bodies could be produced by maintaining porcelain at a constant temperature for lengths of time which lie within the variations of commercial practice. The clay passed into amorphous silica and *sillimanite*, which in turn passed into crystallised *sillimanite*, the solution of *quartz* taking place at the same time. The difference in structure became more marked the higher the burning temperature. The amount of *sillimanite* formed was greater the longer the burning at constant temperature was continued; also the larger and better developed did the crystals become and the greater the amount of *quartz* dissolved by the felspar.

Sillimanite crystals were formed, first, by the gradual change from the amorphous to the crystalline state without the aid of a flux, and, secondly, with the aid of felspar as a flux through solution and recrystallisation of the amorphous *sillimanite*.

Bodies fired for longer periods at lower temperatures had been produced which simulated very closely those fired at higher temperatures for shorter periods, and therefore it was not possible to predict the temperature of burning of porcelain bodies without having some knowledge of composition and length of firing.

Several photomicrographs were shown in illustration.

A. M. J.

251. Glass Furnaces. A. F. Peeters, Holland (Brit. Pat No. **116477**, February 11th, 1918, No. 2439).—In a tank glass-melting furnace having melting and working compartments, the burner or inlet for the heating gases is situated at the end of the working compartment, and the outlet flue at the end of the melting compartment. H. G. C.

252. Glass Furnaces. H. C. Ghijsen and Naamlooze Vennootschap Vitrite Works, Holland (Brit. Pat. No. **124307**, April 9th, 1918, No. 6057).—In a melting furnace, more particularly adapted for use in filling the bases of electric lamps with molten glass, a continuous stream of metal is maintained by heating a small part only of the raw material, and the quantity required for a filling operation is cut off by a pair of blades and led through a conduit into the base or mould to be charged. The raw material is fed down an inclined surface, 3, on to a floor, 4, where it is melted by the flame from a burner, 9. The stream of molten metal is further heated by a burner, 10, and flows to the discharge lip, 6, through a narrow channel formed by vertical wall, 7. Projections, 8, from the roof of the furnace prevent too rapid descent of the raw material, and an inspection opening, 12, is provided on the furnace wall opposite the lip, 6. The cutter blades, 17, 18, are carried by concentric shafts, 15, 16, and are operated at regular intervals from a rotating shaft, 28, of the lamp-making machine through a cam groove, 27, lever, 23, links, 21, 22, and arms, 19, 20. In their open position, the blades are withdrawn into cooling chambers, 30. The lamp bases, 31, are carried

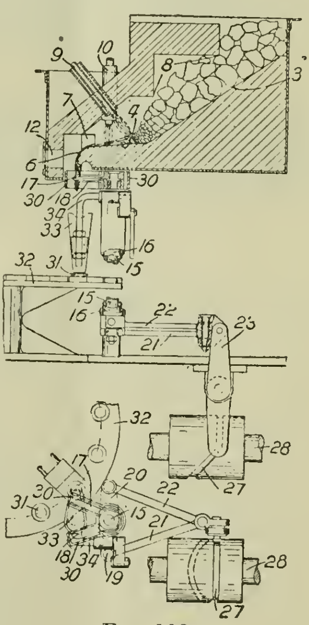


Fig. 108.

by a rotating table, 32, and the cut-off portions of glass are fed thereto by a guide conduit, 33, carried by a pivoted arm, 34, connected to a treadle, operation of which moves the delivery end of the conduit out of the path of the lamp bases. H. G. C.

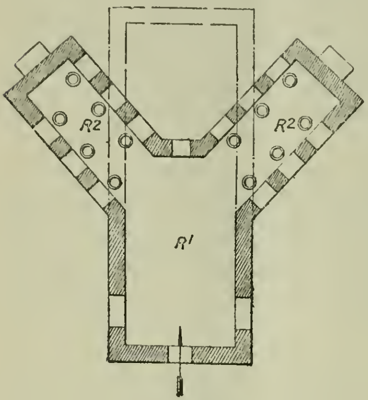


Fig. 109.

253. Glass Furnaces. A. F. Peeters, Holland (Brit. Pat. No. **123146**, February 11th, 1918, No. 2440).—Two or more working spaces, R^2, are connected with a single melting space, R^1, the total cross-sectional area of the working spaces being in excess of that of the melting space. The heating gases pass from the melting space through the working spaces, or *vice versa*.

H. G. C.

254. Reverberatory Furnaces for Glass Manufacture, etc. T. B. Kitson (Brit. Pat. No. **122672**, December 27th, 1917, No. 19116).—The air for combustion is heated in an intermediate chamber or flue arranged between the furnace crown and an upper waste flue, without previously passing through a regenerator, the air and waste gas flues being straight and unobstructed, and the air and waste gases passing through them in the same direction. The exhaust ports, or outlets, for the waste gases also serve as troughs, or spouts, for the discharge of molten glass, etc. Fig. 110 is a vertical section of a gas-fired furnace. The air for combustion passes first through a series of parallel passages, *g*, beneath the furnace, and then through a chamber or flue, *h*, between the furnace crown and the waste-gas flue, *d*, being finally delivered to the furnace chamber through ports alternating with gas-supply ports, *j*. Fig. 111 shows the arrangement whereby the waste-gas outlets are formed by the outflow spouts, *d'*, for the molten glass. H. G. C.

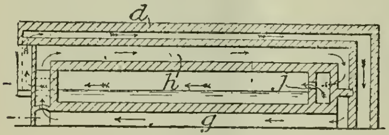


Fig. 110.

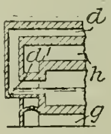
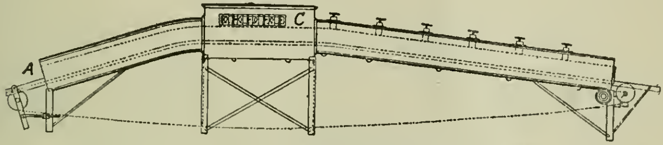


Fig. 111.

255. Glass-annealing Lehrs. J. Keith and G. Keith (Brit. Pat. No. **123254**, June 13th, 1918, No. 9727).—A glass-annealing lehr, through which goods are carried by an endless conveyer, consists of a long tunnel with a portion inclined upwards from the feeding end, *A*, Fig. 112, a gas-fired heating chamber, *C*, at the highest point, and a long, downwardly inclined discharge part, the end of which is at a slightly higher level than the inlet to the tunnel. The heating chamber is formed as a muffle, and the products of combustion from high-pressure burners, *H*, Fig. 113, pass from the surrounding flues to the discharge part of the tunnel, from which they escape at the end, and through dampered openings about its length. Pyrometers, *K*, are fitted in the heating chamber and along the discharge part, and observation openings, *J*, are provided opposite the burners. H. G. C.

Fig. 112.



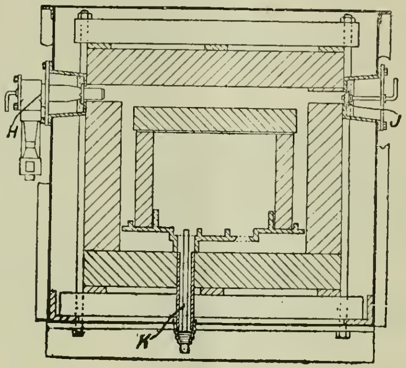


Fig. 113.

256. Glass Furnaces. E. Roirant, France (Brit. Pat. No. **117452**, June 27th, 1918, No. 10572. Convention date, July 12th, 1917. Not yet accepted. Abridged as open to inspection under Sec. 91 of the Act).—Discharging.—Glass is discharged from a melting furnace into a receptacle, 11 (Fig. 114), which can be moved from its receiving position within a chamber, 2, adjoining the furnace to the gathering point. As shown, the receptacle 11 is mounted between arms, 9, pivoted on a shaft, 8, and passes to and from the chamber, 2, through an opening, 5, in the front wall. The

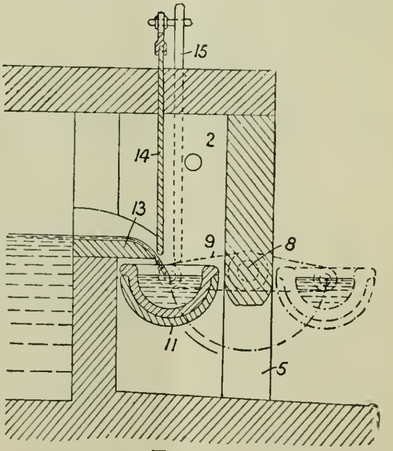


Fig. 114.

delivery of glass over the lip, 13, is controlled by a gate, 14, which may be automatically operated by the movement of the receptacle through a rod, 15. The chamber, 2, may be heated either by gases from the melting furnace or by separate burners.
H. G. C.

257. Electric Furnaces. H. A. Greaves and H. Etchells (Brit. Pat. No. **115866**, April 11th, 1917, No. 5072).—Resistance furnace.—Granular resistance material is contained in ducts, *d*, looped around the furnace chamber, *b* (Fig. 115), and separated by material which, when hot, allows a certain amount of current leakage between the ducts. Suitable materials for the loose resistance are ground coke, retort carbon, kryptol, carborundum, siloxicon, silundum, or a mixture of minerals, such as cryolite and chromite. The partitions between the ducts may be of chromite, magnesite, carborundum, or silundum. A layer of resistance material, d^1, beneath the furnace chamber connects the material in the ducts. Passages may be provided for replenishing the ducts with resistance material. Electrodes, *g*, entering the ducts, preferably from above, are arranged in groups of two or three for polyphase currents, or are alternately of opposite polarities when single-phase or direct current is used. Supply transformers may be arranged for alternative series or parallel connection, for use at starting and in normal working respectively. Further regulation may be effected by auto-transformers in the primary circuits. The furnace may be used for melting, refining, heating, annealing, etc.
H. G. C.

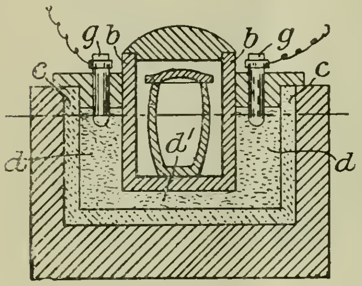


Fig. 115.

258. Gaseous-fuel Furnaces. H. N. Davis and W. R. Twigg (Brit. Pat. No. **122673**, December 28th, 1917, No. 19189).—Furnaces specially adapted to be fired by coal gas as supplied by gas companies are provided with reversible regenerators formed entirely within the furnace structure, to which air is supplied under pressure. Fig. 116 is a diagrammatic section of such a furnace, gas being supplied by the pipes 17 and 18 alternately, and air under

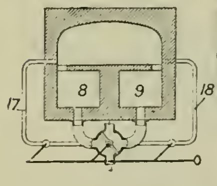


Fig. 116.

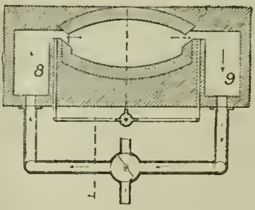
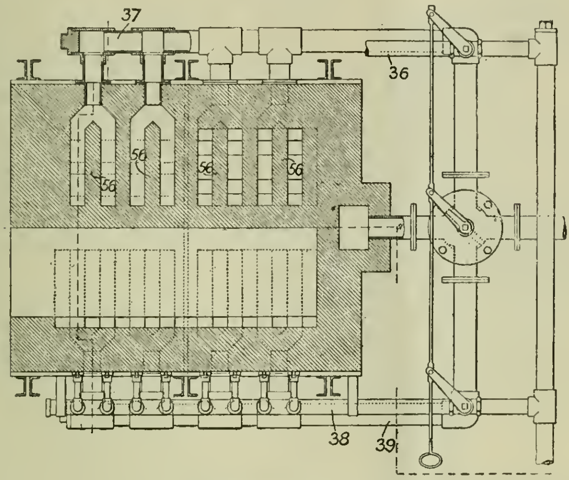


Fig. 117.

pressure through the regenerators 8, 9, alternately, the regenerators being arranged beneath the floor of the furnace chamber. Fig. 117 is a similar view of a furnace with the regenerators at the ends of the furnace. Figs. 118 and 119 are more detailed sectional views of a furnace heated by a row of gas burners on each side, gas being supplied at either side alternately from pipes 36, 38, while

Fig. 118.



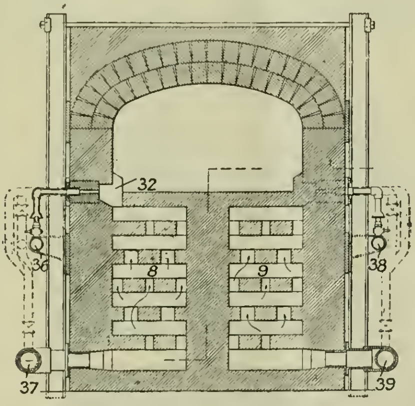


Fig. 119.

air is supplied under pressure through the regenerators 8, 9, alternately, from pipes 37, 39, by means of reversing valves. The burners deliver into spaces 32 at the level of the floor of the furnace chamber, into which the heated air from the regenerators is delivered. The waste products of combustion pass through the regenerator which is not in use for heating the air. The regenerators are divided into sections independently supplied with air, as shown in the sectional plan view, Fig. 118, and each section is further divided into two by a partition, 56. Unheated air may be supplied to the burners by connections from the air-supply pipes, as indicated by dotted lines in Fig. 119. H. G. C.

259. Muffle Kiln for Firing Pottery, etc. W. BENNETT (Brit. Pat. No. **117147**, July 16th, 1917, No. 10257).—A combustion chamber, *c* (Fig. 120) is arranged longitudinally beneath the floor of the kiln about midway of its breadth, and is supplied with gas and air through passages, *b*, *e*, extending from one side, the gas being admitted to the passages, *e*, from a side-main, *a*. The gas and air passages are preferably grouped in, say, four sets, each having an air passage, *e*, between two gas passages, *b*, and the combustion chamber may be divided by transverse partitions. The supplies of gas and air to the passages, *b*, *e*, are controlled by suitable valves. In a modification, the air passages are divided into two parts, one above the other, by a partition, one part leading direct to the combustion chamber, and the other passing to the opposite side of the kiln and returning to the combustion chamber. H. G. C.

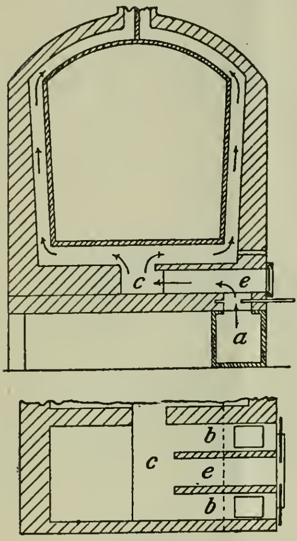


FIG. 120

260. Tunnel Kilns. G. H. BENJAMIN, U.S.A. (Brit. Pat. No. **117383**, November 12th, 1917, No. 16592).—A continuous tunnel kiln for use in the manufacture of tiles, pottery, and the like consists of a main chamber or tunnel heated by closed combustion chambers arranged in line along its sides in which gas is burnt, and by the circulation through the main chamber, and through the goods, of hot air which, after

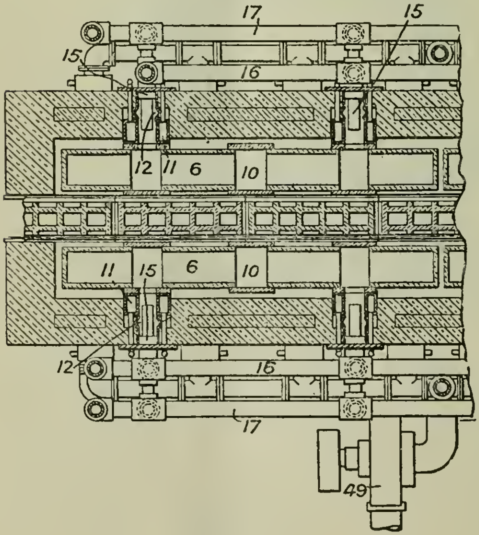


FIG 121.

exhaustion from the goods chamber, may be in part used for combustion. Fig. 121 shows a sectional plan of one end of the kiln, and Figs. 122 and 123 show transverse sections through different parts of it. Gas and air are supplied by pipes, 16, 17, and burners, 15, to each combustion chamber, 6, at two points as shown, or at one point only. through a corrugated section, 12, and a water-cooled sleeve, 11, and the combustion products pass away at 10 through arched flues, 26 (Fig. 123), to a multitubular air-heater, 35, and thence to a chimney. In the arrangement shown, the outlet portion, 10, of each combustion chamber is situated between two burners, 15. In a modification, each combustion chamber has one burner only, the outlet portion being at one end. Some of the hot air from the air-heater, 35, is drawn off by a pump for combustion in the burners, gas being supplied by another pump. The gas and air are supplied preferably at pressures of one and one and a-quarter lb. per sq. in. respectively. The remainder of the hot air from the heater, 35, is led by pipes, 38, to flues, 39, beneath the combustion chambers, 6, and circulates through the goods, 41, passing away through flues, 44, 45, formed in the trucks conveying the goods through the kiln, and through flues, 46, 47, in the base

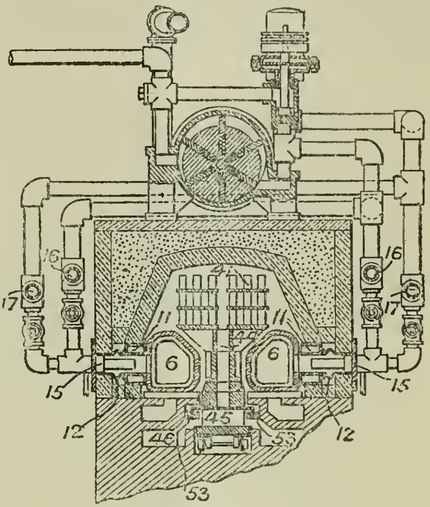


Fig. 122.

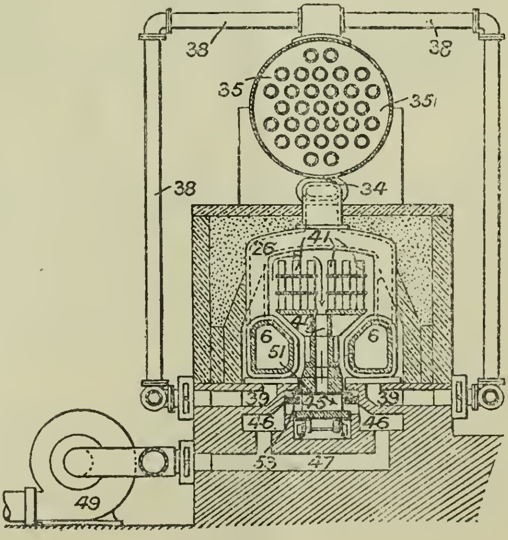


Fig. 123.

of the kiln to the exhaust fan, 49. The passages, 45, are sealed from the interior of the kiln by sand seals, 53, in which move the down-turned edges of a plate on the truck. Cold or tempered air may be admitted to the kiln by shutting a valve on a pipe connecting the air-heater and the air pump, and opening another inlet on the air pump. The fan, 49, may deliver the air withdrawn from the kiln to the inlet, 34, of the air-heater for use again. H. G. C.

261. Furnaces and Kilns for Metal Heating or for Pottery. H. Francart (Brit. Pat. No. **122742,** March 21st, 1918, No. 5027).—A furnace or kiln for metal heating or for use in the manufacture of pottery, etc., comprises combustion and heating chambers arranged side by side and connected at top and bottom so that a continuous circulation of combustion products will take place from the combustion chamber, down through the heating chamber, and back again to the combustion chamber. In the kiln shown, a number of combustion chambers, 3, are arranged at the two sides of the heating chamber, 5, with which they are in communication by openings at the top and bottom respectively. Gas and air are burnt at the lower ends of the combustion chambers, and the products circulate through the heating chamber as shown by the arrows, finally escaping by an end flue, 17. The combustion chambers may be filled with chequer brickwork, which acts as a heat accumulator. H. G. C.

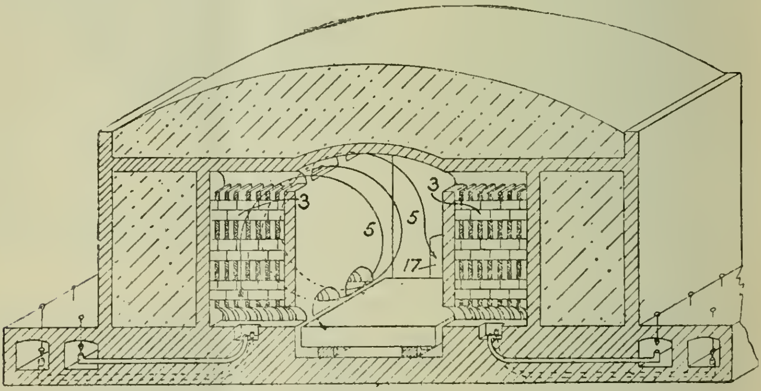


Fig. 124.

262. Coke Ovens. E. Hurez, France (Brit. Pat. No. **123099,** February 6th, 1919, No. 2974. Convention date, January 20th, 1918. Addition to 107178. Not yet accepted. Abridged as open to inspection under Sec. 91 of the Act).—A coke oven of the type described in the parent specification is modified so that it can be heated by crude gas direct from the ovens, by the oven gas after the removal of by-products, or by a poor gas, such as blast-furnace or producer gas. When working with crude gas, dampers *B* in passages connecting the ovens, *G*, with the heating-flues, *D*, are opened, and the damper *I* is closed. Air is supplied either through plugs inserted in place of the stoppers, *R*, or through the chamber, *V*, and channels, *Z*, and the products pass down through the

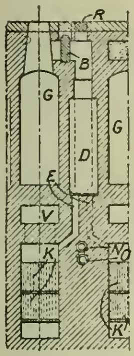


Fig. 125.

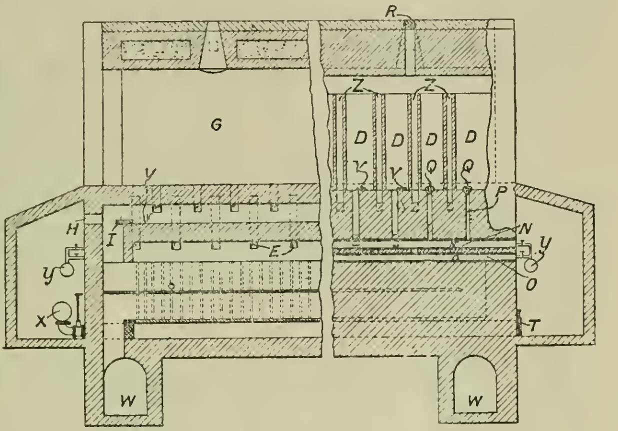


Fig. 126

heating flues, *D*, passages, *E*, and the vertical channels of the recuperator, *K*, to the chimney flues, *W*. In the second method of operation, washed oven gas from the mains "*y*" is supplied to two superposed flues, *N*, *O*, and passes thence through passages, *P*, to burner nozzles, *Q*, at the base of the flues, *D*. Air enters at the damper, *T*, passes through the vertical channels of the recuperator, and enters the flues, *D*, through the passages, *E*. The products of combustion pass downwards through the flues, 2, to the chamber, *V*, and pass thence along the horizontal passages of the recuperator to the chimney flue, *W*. The third method of working, the poor gas from a main, *X*, is supplied to alternate recuperators, and enters the heating-flues through the corresponding passages, *E*, of which there are two for each heating flue. The air is supplied as in the second method through the remaining recuperators and the corresponding passages, *E*, in connection with which damper blocks, *v*, are provided. The form of recuperator block used is shown in Fig. 127. H. G. C.

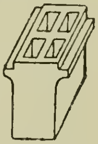


Fig. 127.

263. Heat Regulator for Ovens and Kilns. A. Tilstone and T. Tilstone (Brit. Pat. No. **125486**, March 14th, 1918, No. 4493).—A heat regulator for ovens and kilns for firing pottery and the like consists of a detachable "grid" or perforated block or set of blocks which are fitted to the outlet and other flues of the kiln, etc., to check the flow of gases. Fig. 128 shows such a perforated block. It may be mounted in a metal ring, *c*, and may be raised about a pivot, *d*, by a cord, *f*. Two or more such blocks may be fitted one above another, so that by rotating the upper block the ring of apertures, *b*, may be partly closed. Fig. 129 shows a modification, particularly for an enamel kiln, consisting of a hollow, perforated dome, *a′*, fitted upon a tube, *j*, which is fitted into the flue in the upper part of a kiln. The block shown in Fig. 128 is adapted to the inlets and outlets of an up-draught oven and to the outlet of a down-draught oven. The devices may also be used for ventilating the heating and cooling chambers of tunnel ovens and other heating apparatus. H. G. C.

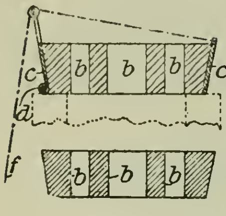


Fig. 128.

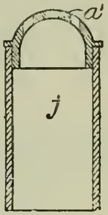


Fig. 129.

264. Indicator for Furnaces. G. Alliata, Switzerland (Brit. Pat. No. **115423**, April 11th, 1918, No. 6175. Convention date, May 3rd, 1917. Not yet accepted. Abridged as open to inspection under Sec. 91 of the Act).—An indicating device for use in connection with furnaces comprises a pointer or pointers controlled by pressure differences between, or the pressures in, two chambers, through which flow gaseous fluids used in combustion, for example, primary and secondary air or gas and air. Variations in combustion are indicated by deflection of the pointers, and by suitably adjusting the supply valves of the two fluids normal conditions can be re-established. In one form of apparatus, shown diagrammatically in Fig. 130, the primary air for the combustion of coke in a furnace, 1, is supplied under control of a valve, 4, through a chamber, 4′, while secondary air is supplied through a similar chamber, 5′, under control of a valve, 5. From the chambers, 4′, 5′, pipes, 6, 7, lead to bell floats, 9, 9′, which operate, through suitable levers, pointers, 12, 13, moving over scales, 15. The apparatus is so adjusted that, when combustion conditions are normal, the pointers will stand at the same gradua-

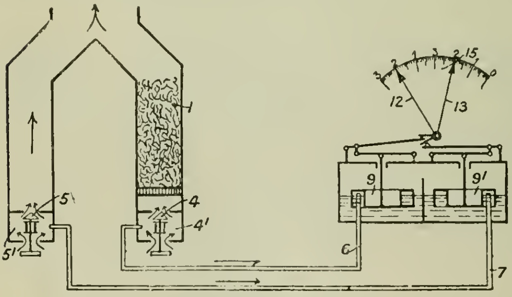


Fig. 130.

tion on the two scales. When variations occur, for example, owing to clinkering of the grate, the pointers will be deflected in opposite directions, and the valves, 4, 5, can then be operated until the pointers indicate that balanced conditions are re-established. In a modification, the two pointers are connected by a rod pivoted about a knife-edge, and in a further modification, the two bell floats are controlled by the pressure-differences between two points in the supply conduits. The bell floats may be replaced by a diaphragm operating a single needle. H. G. C.

265. Reversing Valves for Regenerative Furnaces. H. N. Davis and W. R. Twigg (Brit. Pat. No. **122674**, December 28th, 1917, No. 19190).—The gas and air reversing valves are simultaneously operated by rigid connections. As shown in Fig. 131, which is a plan view, the air valve, 3, and the gas valves, 13, 14, are arranged with their axes vertical in the same vertical plane, and their actuating levers are connected together by a common actuating rod, 20. A similar arrangement is described in which the valves have their axes horizontal. Fig. 132 shows in elevation an arrangement in which the gas valve, 42, and the air valve, 4, are co-axially arranged with a common spindle. Three such sets of valves may be connected together by chain gearing so as to be operated simultaneously. Valves arranged at the rear of the furnace may be operated by a spindle extending to the front, and weights may be fitted to retain the valves in their operative positions. Valves for admitting compressed air to the burners may be arranged to be operated by the same means as the reversing valves.

H. G. C.

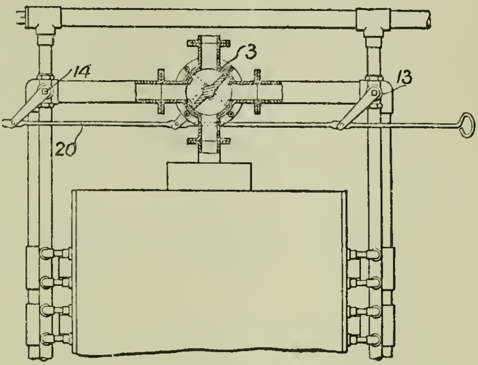


Fig. 131.

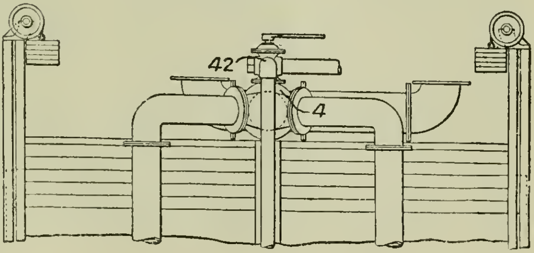


Fig. 132.

VIII.—Chemical Analysis.

266. The Gravimetric Determination of Calcium and Separation of Calcium from Magnesium. L. W. Winkler (*Zeitsch. angew. Chem.*, 1918, **31**, 187, 203, 214).—An examination was made of the method of estimating calcium as oxalate or carbonate. The following conclusions were drawn:—Calcium, as oxalate, was best precipitated by addition of ammonium oxalate to a boiling solution containing acetic acid and excess of ammonium chloride. The oxalate was filtered off after standing twenty-four hours, washed, dried at 100°, and weighed as such rather than as oxide after ignition. This reduced the liability to error when sulphate was present, since the oxalate and sulphate of calcium have about the same molecular weight. High results were obtained when sodium salts were present. Potassium salts and chromates did not affect the determination. Calcium was most successfully precipitated as carbonate in the absence of ammonium salts and also of chromates.

The separation of calcium from magnesium was made by precipitation of calcium as oxalate as indicated above and the subsequent precipitation and weighing of magnesium as ammonium magnesium phosphate. F. W. H.

267. The Alkalimetric Determination of Small Amounts of Magnesium. P. L. Hibbard (*J. Ind. Eng. Chem.*, 1919, **11**, 753).—This method, with various modifications, is based on Bruckmüller's estimation of magnesium by titration of ammonium magnesium phosphate. The author found that with his modifications the method was convenient and exact for the determination of quantities of between 5 mg. and 0·1 mg. The principal changes introduced were: (1) Use of the Gooch crucible for filtration, whereby it is possible to wash the precipitate in the most efficient manner with the least quantity of solution. (2) Use of neutralised alcohol, followed by water solution of ammonium magnesium phosphate for washing. (3) Use of methyl-red instead of methyl-orange as indicator.

The method is alkalimetric, depending for success on obtaining the magnesium in a definite compound, ammonium magnesium phosphate, the alkalinity of which may be accurately determined by means of standard acid. The solution must be free from other bases precipitable by the phosphate ion in alkaline solution. It was convenient, in most cases, to use the solution from which the calcium had been separated as oxalate. The volume should be small. For amounts less than 1 mg., 5 c.c.; 1 to 3 mg., 10 c.c.; in excess of 5 mg., 20 c.c. Other soluble salts increased the solubility of the precipitate, and hence should be absent. Ammonium salts should be removed by evaporation and ignition, or by evaporation with nitric and hydrochloric acids. The quantity of ammonium salts formed in making the separation of calcium as oxalate ordinarily did not interfere with precipitation of the phosphate.

The author gave two methods of precipitation, one in the cold and Schmitz's method for hot precipitation if the solution contains much ammonium salts which are not convenient to remove. (*a*) *Cold precipitation.* The solution should contain one-tenth to two-tenths of 1 per cent. ammonium chloride and enough free ammonia to give a distinct odour. One c.c. of a 1½ per cent. solution of ammonium sodium hydrogen phosphate is added for each 1 mg. of magnesium present, and the mixture shaken well. After ten minutes, one-third of the volume of strong ammonia is added and allowed to stand for at least two hours. (*b*) *Hot precipitation.* The solution is acidified slightly with hydrochloric acid, heated to boiling, the necessary amount of ammonium sodium hydrogen phosphate added, then one-third of the volume of strong ammonia, and allowed to stand for two hours or more.

A Gooch crucible with a moderate thickness of paper pulp is used, and the precipitate filtered with moderate suction, washed two or three times with 95 per cent. neutral alcohol, and then four times with 5 c.c. portions of a saturated aqueous solution of ammonium magnesium phosphate. The paper pulp with the precipitate is returned to the flask with water and titrated.

For the titration a few drops of 1 per cent. alcoholic solution of methyl-red as indicator are added, then acid until there is about 5 c.c. in excess. After complete solution of the precipitate, the acid is titrated back with alkali of the same strength.

One c.c. of $N/50$-acid$\equiv$0·24 mg. magnesium. When more than 2 mg. of magnesium were present, the colour change was not sharp.

C. M. M.

268. The Gravimetric Determination of Arsenic Acid. L. W. Winkler (*Zeitsch. angew. Chem.*, 1919, **32**, 122).—The arsenic acid was reduced by means of potassium thiocyanate in the presence of hydrochloric acid. To a quantity of the solution of arsenic acid containing about 0·01 to 0·15 gram of As_2O_5 was added 10 c.c. of hydrochloric acid and 5 c.c. of 20 per cent. solution of potassium thiocyanate. Sulphuretted hydrogen was then passed into the solution for about one hour and the latter allowed to stand. After about eighteen hours the precipitate, consisting of a mixture of arsenic sulphide and sulphur, was filtered off, washed, dried at 100°, and weighed. The arsenic sulphide might then be dissolved in ammonia, oxidised with hydrogen peroxide, precipitated as ammonium magnesium arsenate, and weighed as such, or, after ignition, as magnesium pyro-arsenate. F. W. H.

269. The Gravimetric Determination of Phosphoric Acid. L. W. Winkler (*Zeitsch. angew. Chem.*, 1919, **32**, 99).—To 100 c.c. of the phosphate solution, containing about 0·1 gram of P_2O_5, were added 2·5 grams of ammonium chloride. The solution was then boiled and 10 c.c. of 10 per cent. ammonia solution added. For precipitation of the phosphoric acid 0·5 c.c. of a solution was added containing 10 grams of magnesium sulphate and 5 grams of ammonium chloride to 100 c.c. of water. The mixture, while still hot, was stirred until the precipitate became crystalline, and then a further 9·5 c.c. of the magnesium sulphate solution were added slowly. When quite cold, the precipitate was filtered off, washed with 1 per cent. ammonia solution, dried, and then weighed as ammonium magnesium phosphate or ignited and weighed as magnesium pyrophosphate.

When the phosphoric acid was previously precipitated as ammonium phosphomolybdate the final figures were found to be slightly high to the extent of about 0·3 milligram on amounts from 0·05 gram to 0·25 gram. Sodium and potassium chlorides did not affect the results when the precipitate was weighed as ammonium magnesium phosphate, but potassium chloride caused high results when the precipitate was weighed as magnesium pyrophosphate. F. W. H.

270. A Convenient Method of Analysis of Fluorspar and of Basic Slags containing Fluorine. G. R. Doyle (*Chem. News*, 1919, **118**, 304).—The finely ground sample was extracted by repeated evaporations with glacial acetic acid, and the excess acid finally expelled by heating in a steam oven. The heated material was then dissolved out in water, boiled, and filtered. The residue contained all the lime existing as calcium fluoride, all iron and alumina, and the greater part of the silica. The filtrate contained soluble lime and silica, manganese, magnesia, and lead. The silica in the residue was determined by using hydrofluoric acid, and the remainder was converted to sulphates by treatment with sulphuric acid, ignited, and weighed. The iron and alumina were determined, deducted from the weight of the sulphates, and the remaining calcium sulphate calculated to calcium fluoride.

The filtrate was evaporated to dryness with 5 c.c. of hydrochloric acid and a few drops of nitric acid, baked, and taken up in 5 c.c. of hydrochloric acid, diluted, and filtered. The silica so obtained was determined and added to the amount from the residue. Manganese was precipitated by bromine and ammonia, estimated as usual, and calculated as MnO. Lime was precipitated as oxalate, ignited to oxide, and weighed. Magnesia was estimated as pyrophosphate. F. W. H.

271. The Estimation of Zinc and Calcium in the Presence of Lead. E. Nyman (*Chem. News*, 1919, **119**, 75).—Ammonia was added to an acid solution containing the zinc, calcium, and lead until the solution was strongly alkaline. The solution was then acidified with acetic acid. Any precipitate formed at this stage was dissolved by addition of ammonium acetate. The solution was then rendered slightly alkaline with ammonia and titrated, at a temperature from 70° to 80°, with potassium ferrocyanide solution, an acid solution of uranium acetate being used as external indicator.

For the estimation of calcium, the solution was prepared in the same way as for zinc up to the slightly alkaline stage. The calcium was then precipitated as oxalate by addition of excess of ammonium oxalate. F. W. H.

272. The Estimation of Zirconium. P. Nicolardot and A. Reglade (*Compt. rend.*, 1919, **168**, 348).—The solution of zirconium was rendered either neutral or acid with sulphuric acid. The zirconium was precipitated by the addition of ammonium phosphate, filtered, washed, ignited, and weighed as pyrophosphate. This method gave complete separation of zirconium from aluminium provided that the acidity was equivalent to 10 per cent. sulphuric acid, and from iron and chromium if 20 per cent. of acid were present. The authors used the factor 0·487 for the conversion of the weight of pyrophosphate to oxide of zirconium. F. W. H.

273. The Solubility of Aluminium Hydroxide. E. H. Archibald and Y. Habasian (*Trans. Roy. Soc. Canada*, 1917–1918, iii, **11**, 1).—The authors determined the solubility of aluminium hydroxide in solutions of ammonia of different strengths and in ammoniacal solutions of ammonium nitrate or potassium nitrate. Freshly precipitated aluminium hydroxide was shaken with the particular solvent in sealed tubes for twelve hours in a thermostat at 20°, and also at 30°. The contents of the tubes were filtered and certain weights of the filtrates evaporated to dryness in platinum crucibles and the residues ignited and weighed. It was found that the solubility of aluminium hydroxide increased with the concentration of ammonia until a solution of semi-normal strength was reached; the solubility then decreased as the ammonia concentration increased. The presence of ammonium nitrate decreased the solubility of aluminium hydroxide in ammonia, whilst presence of potassium nitrate considerably increased the solubility.

It was recommended that aluminium hydrate should be precipitated in a solution containing a very slight excess of ammonia and should be washed with a 10 per cent. solution of ammonium nitrate. F. W. H.

274. The Technical Analysis of Auckland Clays. A. B. Jameson (*N.Z. J. Sci. and Tech.*, 1919, **2**, 209).—The author adapted the method of analysis used by Zschokke, a method which combined certain details of the elutriation process of separation, or "mechanical analysis," and Seger's "rational analysis." Elutriation alone could not separate colloidal clay matter completely, and failed entirely with certain calcareous clays. Seger's method alone was unsatisfactory, since sulphuric acid decomposed, not only the actual clay, but also many minerals frequently associated with a plastic clay.

The "combined method" used consisted, first, in the elutriation of the clay into a clay fraction, *A*, and a sand fraction, *B*, these two portions then being separately extracted with 10 per cent. hydrochloric acid. The material after elutriation was dried, and a known weight rubbed gently with a pestle in a porcelain dish containing about 100 c.c. of the 10 per cent. hydrochloric acid until disintegrated. After digesting for thirty minutes on a steam-bath, the contents of the dish were filtered, and the residue washed, dried, and weighed. A known weight (about 3 grams) of the residue was then taken to the fuming stage with 10 c.c. of 50 per cent. sulphuric acid. After cooling and diluting with water, the residue was filtered off, washed, dried, and weighed. The results were indicated thus:—

A.	(*a*) Insol. in HCl, treated with H_2SO_4.	(*c*) Insoluble in H_2SO_4: Quartz, felspar, mica, etc., determined by microscopic investigation.
		(*d*) Soluble in H_2SO_4: Clay, reckoned by difference.
	(*b*) Soluble in HCl.	Estimated by difference: $CaCO_3$, $CaSO_4$. $MgCO_3$, $MgSO_4$, and FeO, determined by microscopic investigation.
B.	(*e*) Insoluble in HCl.	Coarser grains of (*c*).
	(*f*) Soluble in HCl.	Estimated by difference, coarser grains of (*b*)

Thus fraction *A*, the "clay fraction," gave actual clay, fine sand, etc., and fine carbonate, etc., whilst *B*, the "sand fraction," gave coarse sand, etc., and coarse carbonates, etc. The results obtained for any particular clay therefore indicated the means of modifying composition where necessary.

The results of analyses of various Auckland clays were given. The shrinkage of moulded samples on drying and firing was also determined. The clays were separated by elutriation into two fractions, the "clay fraction" and the "sand fraction," and then new samples were made by mixing together various proportions of the two fractions. The new products were then fired, and contractions and porosities were determined. An attempt was made to show how the firing properties of the clays could be interpreted from the analytical data. F. W. H.

275. Precautions Necessary in Grinding Samples of Coke for Analysis. A. E. Findley (*J. Soc. Chem. Ind.*, 1919, **38**, 93T).—Experiments were undertaken in order to investigate the widely different results obtained in the determination of ash in coke. All samples ground in an iron mill were magnetic, but one sample of coke was itself magnetic, probably owing to reduction of the pyrites in the coal during coking. Samples of coal yielding different types of ash were ground in agate or glass mortars and coked in platinum or silica crucibles. The samples of coke obtained were then ground in agate, iron, or glass mortars, and the ash determined. Coke samples ground in either agate or iron mortars were magnetic if obtained from coal rich in iron. The difference between determinations of ash in coke ground in agate and iron mortars was roughly 0·2 per cent. The results justified the conclusions that no very appreciable error in the determination of ash was caused by grinding coarsely-powdered coke to a fine powder in an iron mortar, and that contamination must have occurred during the conversion of small pieces to a coarse powder.

Further experiments on a very hard type of coke confirmed the above conclusions. A large piece of this coke was broken into four approximately equal pieces, and after treatment gave the following results:—

No.	Coarsely powdered.	Finely powdered.	Ash, per cent.	Iron as Fe_2O_3, per cent.
1	In cloth, by hammering.	In agate mortar.	7·0	1·875
2	In iron mill.	In iron mortar.	8·2 ; 8·4	2·915 : 3·125
3	In hardware mortar.	In hardware mortar.	8·5	1·885
4	In agate mortar.	In agate mortar.	7·15	1·885

All portions were magnetic.

The high ash in portion (2) was evidently due to iron, whilst that in portion (3) was due to extraneous matter derived from the hardware mortar. The final conclusions were:—

(1) The largest amount of abrasion occurred during the breaking down of small pieces to coarse powder.

(2) The grinding of coarse powder to fine powder did not appreciably increase the percentage of ash.

(3) The use of a linen bag for breaking down offered a satisfactory solution of the difficulty, since the effect of abrasion of the linen on the percentage of ash was negligible. F. W. H.

276. Comparative Tests of Palan and Rhotanium Ware as Substitutes for Platinum Laboratory Utensils. L. J. Gurevich and E. Wichers (*J. Ind. Eng. Chem.*, 1919, **11**, 570).—The authors dealt with a series of tests carried out to determine the suitability of the alloys of gold and palladium, known as "rhotanium" and "palan," as substitutes for platinum in laboratory ware. The tests were of two types, the aim being to determine the resistance of the materials to chemical reagents and their behaviour upon heating. Tables were given of the observed changes in weight of the crucibles tested when treated with various reagents, namely, boiling hydrochloric, nitric, and hydrofluoric acids, cold sulphuric acid, boiling solutions of ferric chloride and of 20 per cent. sodium hydroxide, and fused sodium hydroxide, sodium carbonate, and potassium pyrosulphate.

The tests showed that rhotanium-*A* ware was superior to platinum both of high (2·4 per cent.) and low (0·6 per cent.) iridium content in respect to its resistance to loss on heating. The losses on treatment with acid, after heating, were about equal. In most tests it appeared to be superior to platinum, except when treated with nitric acid, boiling 10 per cent. ferric chloride solution, and for fusions with sodium hydroxide. The only objection raised to its use was the rather low melting point of the alloy, making it impossible to blast or heat strongly without melting it. Palan and rhotanium-*C* behaved towards reagents in much the same way as rhotanium-*A*, except that they were not suitable for potassium pyrosulphate fusions and were inferior to grade *A* for sodium hydroxide fusions. The only striking distinction between rhotanium-*C* and palan was the latter's slight superiority in the case of potassium pyrosulphate fusions.

Palan and both grades of rhotanium could all be used to advantage in the electrolysis of chemical solutions, but only as cathodes. As anodes, the alloys are worthless.

The solubility of platinum is recognised and allowed for in exact methods of analysis. With palan and rhotanium, both gold and palladium may pass into solution, requiring somewhat different treatment for their elimination. C. M. M.

277. Sodium Pyrogallate Solution as an Absorbent for Oxygen. G. W. Jones and M. H. Meighan (*J. Ind. Eng. Chem.*, 1919, **11**, 311).—Experiments were made by the authors for the purpose of determining the feasibility of using sodium hydroxide to replace the more expensive potassium hydroxide in pyrogallate solutions for the absorption of oxygen.

Tests made over a wide range of concentrations of the various reagents showed that the rate of oxygen absorption in sodium pyrogallate solutions increased with the dilution of the sodium hydroxide, and for any given concentration the rate of absorption was proportional to the concentration of the pyrogallic acid.

It was found that sodium pyrogallate solutions made by using sodium hydroxide solutions of less than 1·30 specific gravity gave off carbon monoxide, which increased with the dilution; also all sodium pyrogallate solutions gave off carbon monoxide when analysing oxygen samples containing more than 95 per cent. of oxygen.

The following sodium pyrogallate solution was recommended by the authors. Stick sodium hydroxide is dissolved in an equal weight of water, and constitutes the stock sodium hydroxide solution. Stock pyrogallate solution is made up in the proportion of 1 gram of pyrogallic acid to 3 c.c. of water. When ready for use, 5 parts of the sodium hydroxide solution are mixed with 2 parts of pyro.

The authors devised a new apparatus for testing the relative absorption with different solutions, an illustration and description being included in the paper. C. M. M.

278. The Analysis of Natural Gas and the Calculation and Application of Results. R. P. Anderson (*J. Ind. Eng Chem.*, 1919, **11**, 299).—In brief, the method of analysis of natural gas by the combustion method consisted in passing a sample of natural gas slowly into oxygen in which an electrically heated platinum spiral was flowing, the calculations being made from an observation of the contraction in volume resulting from the combustion and of the volume of carbon dioxide formed.

The author described two modifications of the apparatus generally used for the analysis of natural gas. One is a simple device which indicates when no further contraction takes place, that is, when combustion is complete, and the other is the substitution of Pyrex glass for the glass ordinarily employed in the combustion pipette. The necessity for accuracy in the measurement of gas volumes was emphasised.

The calculation of results of natural gas combustions according to the theoretical equations was discussed. A statement of the average number of carbon atoms per molecule of paraffin hydrocarbon in the natural gas was recommended as being more logical than a statement of the percentages of two hydrocarbons forming a mixture equivalent, as regards combustion data, to the one actually burned.

The paper included tables of correction and a description of methods for computing the specific gravity and calorific power of the gas. C. M. M.

IX.—Machinery for the Working of Glass.

279. Bottle-stoppers. Beatson, Clark & Co., and F. Tweeddale (Brit. Pat. No. **117403**, January 11th, 1918, No. 701).—The head, *A*, of a ground-glass bottle-stopper, *D*, is formed so as to extend beyond the bottle rim, *B*, and is provided with a downwardly-directed annular flange, *C*, adapted to overlap the rim, *B*, when the stopper is inserted in the neck, *E*, of the bottle, so as to exclude dust, etc., from the mouth, rim, and lip of the bottle. A ring of cork, rubber, or other padding may be placed within the flange, *C*, or around the rim, *B*. The flange may be arranged to fit the rim, *B*, accurately, and the engaging surfaces may be ground together. The operations of grinding the plug to fit into the neck, *E*, and grinding the flange, *C*, to fit the rim, *B*, may be performed simultaneously. H. G. C.

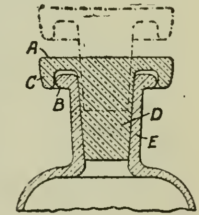


Fig. 133.

280. Bottle-making Machines. H. Wade (Z. V. Lockwood, U.S.A.) (Brit. Pat. No. **123236**, April 26th, 1918, No. 7091).—Consists of mechanism for forming a bottle-neck with an internal groove of the form described in Specification 25440/11. The invention is described as applied to a rotary machine in which a series of five parison moulds are mounted on a table which receives an intermittent movement. Fig. 134 shows in part one of the moulds, *C*, with the groove-forming mechanism in its operative position. The groove is formed by the rotation of bits, 18^b, formed on the upper part of pivoted levers, 18, carried by a block, 17^a, adapted to slide in an opening formed in the adjacent parts of the table, *B*, the fixed mould base-plate, C^1, and an under plate, C^2. The block, 17^a, is mounted on a spindle, 17, sliding in a cross-piece, C^3, and provided with a head, 22^a, to limit its movement. A pinion, 4, is splined to the spindle, 17, but is free to slide thereon. The boss of the pinion carries a cross-pin, 27, passing through a slot in the spindle and connected by a spring, 24, to a pin, 25, fixed to the spindle. The mould, *C*, is shaped to engage the flanged upper part, 11, of the base-plate, C^1, and is adapted to receive the head, C^5, of tongs, shown in Fig. 135, which form the outer part of the neck and serve for the removal of the bottle. The operation of the machine is as follows. Molten metal having been placed in the closed mould, the table is moved forward, and at the next stage a cap is brought down on the mould and compressed air is admitted to force the glass into the neck-forming parts, which are in the position shown in Fig. 134. The mould is held close by a forked piece actuated by a piston and engaging lugs on the mould halves and the gear, 4, which has been raised by a stationary cam, engages a supporting lever, and also gears with a pinion actuated by an electric motor. The levers, 18, are thus revolved, and the groove is formed by the bits, 18^b, which have been moved outwards by the raising of the gear, 4. During the next movement of the table, the bits, 18^b, are moved inwards and the block, 17^b, is lowered. The descent of the block opens communication with a conduit, through which compressed air is admitted to blow the parison. The blowing is effected while the table is at rest, and the mould is locked by a

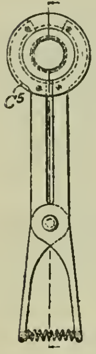


Fig. 135.

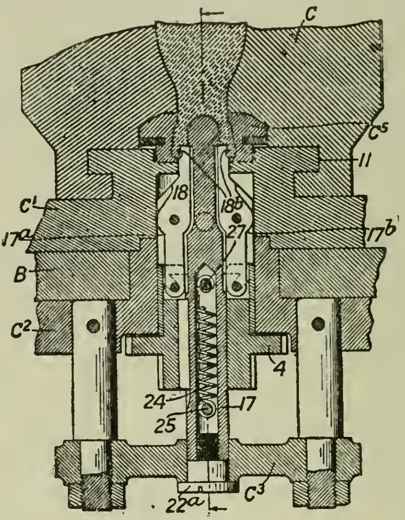


Fig. 134.

device similar to that used at the neck-forming stage. Further movement of the table causes the mould to be opened and allows the parison to be removed in the tongs. The moulds are opened and closed by sliding blocks actuated by a central stationary cam and connected by links to the pivoted mould sections. The table is actuated by a reciprocating piston, and is fitted with locking mechanism as usual. H. G. C.

281. Making Glass Bottles, etc. Sykes & Sugden and T. Jackson (Brit. Pat. No. **124118**, June 8th, 1918, No. 9462). —Relates to the type of turnover machines in which both parison and finishing moulds rotate about a central column, and consists of means for controlling the valves through which suction acts to draw the glass into the neck ring. In the arrangement shown, three turnover heads and three corresponding finishing moulds are employed. The column, 1 (Fig. 136), has a chamber, 8, connected by a pipe, 9, to a pump or other suction apparatus. The chamber, 8, communicates through three sets of pipes, 10, 16 (one only being shown), with the parison moulds, 5, the pipes being fitted with joints, 14, 15, to allow the turnover action. The turnover axis is provided with a valve, which is only open when the parison is upright, and each pipe, 10, is fitted with a valve, 11, the arm, 20, of which is connected by a link, 21, and post, 22, to a slide, 6, carrying the opposite finishing mould. When the parison is being charged, the valve, 11, is open, but it is closed when the slide is pushed inwards at the next station to bring the finishing mould under the turnover head. At the third station, the slide is drawn out to allow removal of the bottle, etc., and thus reopens the valve, 11. Fig. 137 shows the nozzle connected with the parison mould. The air is drawn through recesses, 23, in a liner, 24, fitting in the nozzle, 19, and surrounding the punch, 25. H. G. C.

Fig. 137.

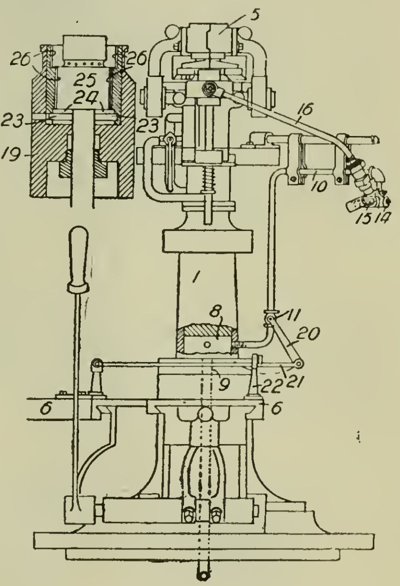


Fig. 136.

282. Glass-making Machinery. A. E. Clegg (Brit. Pat. No. **124356**, July 12th, 1918, No. 11420).—In a machine for pressing jam-jar blanks intended to be blown subsequently in another mould, the usual spring cover-plate, 9 (Fig. 138), through which the plunger, 1, works, is operated by a cam, 11, by means of levers, 5, the ends of which press upon sliding rods, 7. The hand-lever, 13, is mounted on the same shaft, 12, as the cam, 11, and operates the plunger, 1, through arms, 15, and links, 16. By this arrangement, the springs no longer oppose the motion of the plunger when once the roller, 10, rides on the concentric part of the cam, 11, and, in consequence, this motion is easier and more sensitive.

H. G. C.

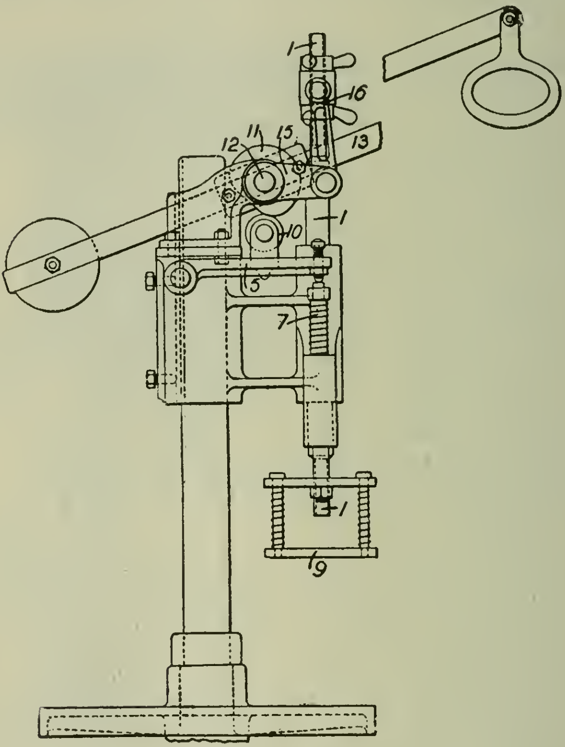


Fig. 138.

283. Washing and Stoppering Bottles. H. Tomson and J. Clayton (Brit. Pat. No. **117208**, November 22nd, 1917, No. 17205).—Relates to apparatus for externally rinsing screw-stoppered bottles after they have been filled, and also to a device for screwing the stoppers tight. The filled bottles, with the stoppers lightly screwed therein, are placed on a rotary table, e, arranged in a tank, d (Fig. 139). The table is divided into four sections, and is rotated by a crown wheel, n, and worm, m, from a pulley, g^1, driven from a shaft, h. On the underside of the table are four cams, s, which, by means of a roller, t, on the lever, t^1, actuate a spring valve, t^2, in a pipe, t^3, leading to a sprayer above the bottles. The table is mounted on its shaft, o, Fig. 140, by a recess engaging a cross-pin, q, in the shaft, so as to be easily removable. The bottles, after being rinsed, are removed to a draining tray, f, where the stoppers are screwed up tight by being pressed against a socket, w, on the end of the shaft, h. This socket carries a recessed rubber block, x (Fig. 141), the friction of which against the head of the stopper is sufficient to screw the stopper home, whereupon it slips on the stopper without damaging it.

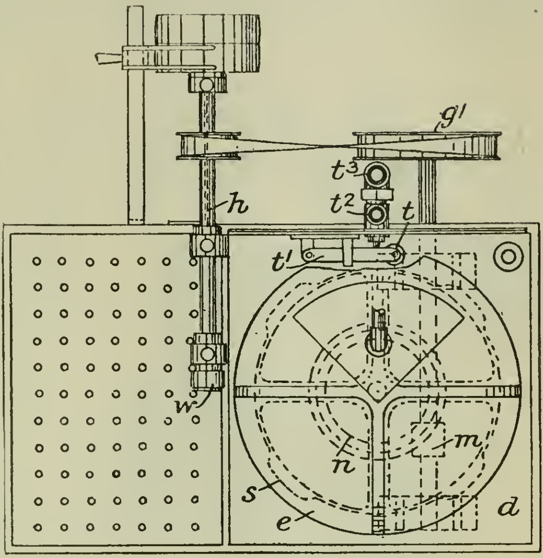


Fig. 139.

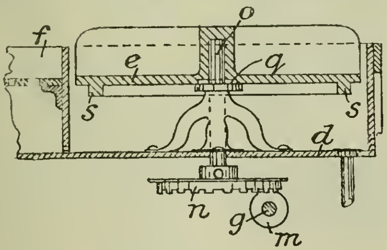


Fig. 140.

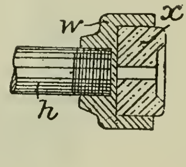


Fig. 141.

H. G. C.

284. Sheet Glass. T. J. McCoy, U.S.A. (Brit. Pat. No **117194**, October 29th, 1917, No. 15735).—Relates to apparatus for forming sheet glass in which the metal is delivered from the furnace in the form of a sheet which, whilst still plastic, is received by a conveyer, which carries it away. The glass from the chamber, 31 (Fig. 142), of the glass-melting tank passes through a channel, 33, fitted with a valve formed of refractory blocks, 34, 35, the movable block, 35, being connected to a float, 41, in the second compartment, 32, so as to keep the level of the glass constant. The valve can be operated by hand when required, and an indicator, 47, is provided to show the level of the glass in the tank. From the chamber, 32, the glass flows over an inclined refractory block, 9 (Fig. 143), in the form of a sheet, 2^1. The block, 9, forms the top of a chamber, *B*, heated by gas burners, 12, and having an opening, 24, in front. A second chamber, *A*, forms an extension of the glass tank, and is partly closed by an adjustable refractory block, 18, which is brought into close proximity with the glass sheet. The chamber, *A*, is heated by gas burners, 13, and is provided with an opening close to the issuing glass. The block, 9, is reduced in thickness at the sides, as shown in Fig. 144, and is formed with upstanding sides, 14. The capstone, 10, of the tank above the block, 9, is formed of reduced thickness at the sides. Lateral air discharge flues are provided to the tank and extension to regulate the temperature,

FIG. 142.

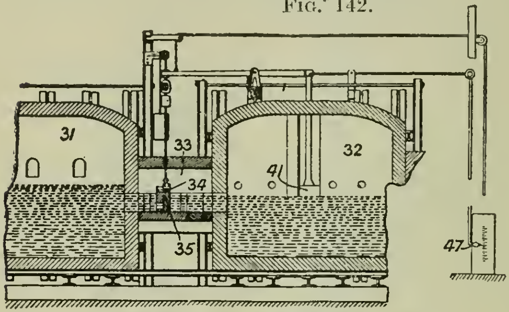
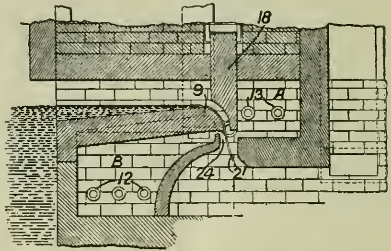


FIG. 143.



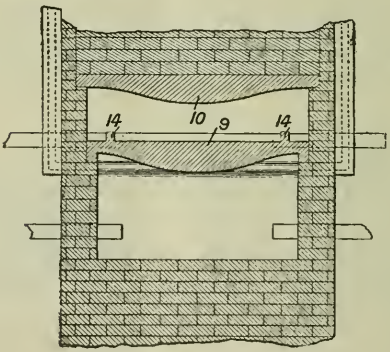


FIG. 144.

and windows are fitted through which the outflow of the glass can be observed. The blocks, 34, 35, may slide in grooves in refractory blocks arranged at the sides of the channel, 33, and the blocks may be provided with additional grooves to receive a solid block for cutting off the glass when the sliding block requires repairing.
H. G. C.

285. Glass-bulb Cutting Machines. British Thomson-Houston Co. (General Electric Co., U.S.A.) (Brit. Pat. No. **125278**, June 15th, 1918, No. 9887).—Consists of a machine for cutting off the necks of miniature lamp-bulbs. The bulbs are delivered to the machine down a curved shoot, 29 (Fig. 145), provided with a longitudinal opening at the bottom, 30, through which the necks project. A disc, 20, is formed with a series of recesses, 21, to receive the bulbs, and is rotated by gearing so as to carry them past a carborundum wheel, 16, which forms a nick in the neck. A spring-arm, 23, normally holds the bulb in the recess, but is raised by cams, 25 and 26, at the receiving and delivering positions. A second spring-arm, 27, presses the neck of the bulb inwards during the cutting operation, so as to ensure fracture. The wheel, 16, is driven by an electric motor, 11, which also actuates the disc through gearing. H. G. C.

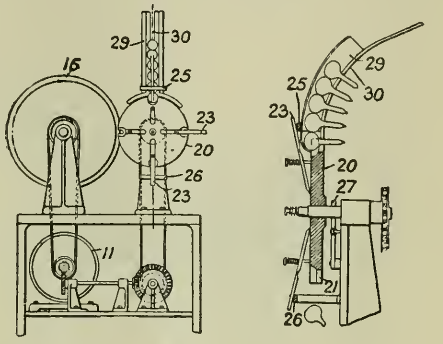


Fig. 145.

286. Grinding and Polishing. F. Cotterell, Australia (Brit. Pat. No. **115661**, May 4th, 1917, No. 6367).—In a glass-polishing machine, tables, 4, 5, are pivoted at adjacent edges so that they may be set horizontal, as shown in full lines, for polishing flat surfaces, or inclined in opposite directions, as shown in dotted lines, for simultaneously polishing the bevelled edges of two sheets. The brackets, 6, in which the tables are pivoted are mounted on a frame formed of a pair of bars, 11, which, by means of a hand-wheel, 21, pinions, and racks, are adjustable along rails, 17, supported on the side members, 2, of the main frame. Each rail is composed of two bars placed face to face and toothed on their lower edges to engage pinions operated by the hand-wheel, 38, whereby they may be moved longitudinally in opposite directions to extend the supporting surface for the bars, 11. The table, 5, is pivoted on an eccentric spindle which may be turned by a handle, 51, to adjust the position of the axis. The angular position of the tables is adjusted by racks, 57, 59, engaged by pinions actuated, through worm gear, by hand-wheels, 72. The spindles, 91, of the polishing tools, 100, are carried by a transverse support, 73, which is moved to and fro in the direction of its length by worm gear and crank and link. The spindles are driven by worm-wheels, 89, 88, from a shaft, 86, carried by the support, 73, and driven by belt; the tools may be lifted off the work by means of hand-levers, 102, and links coupled to cross-heads, 94, secured to

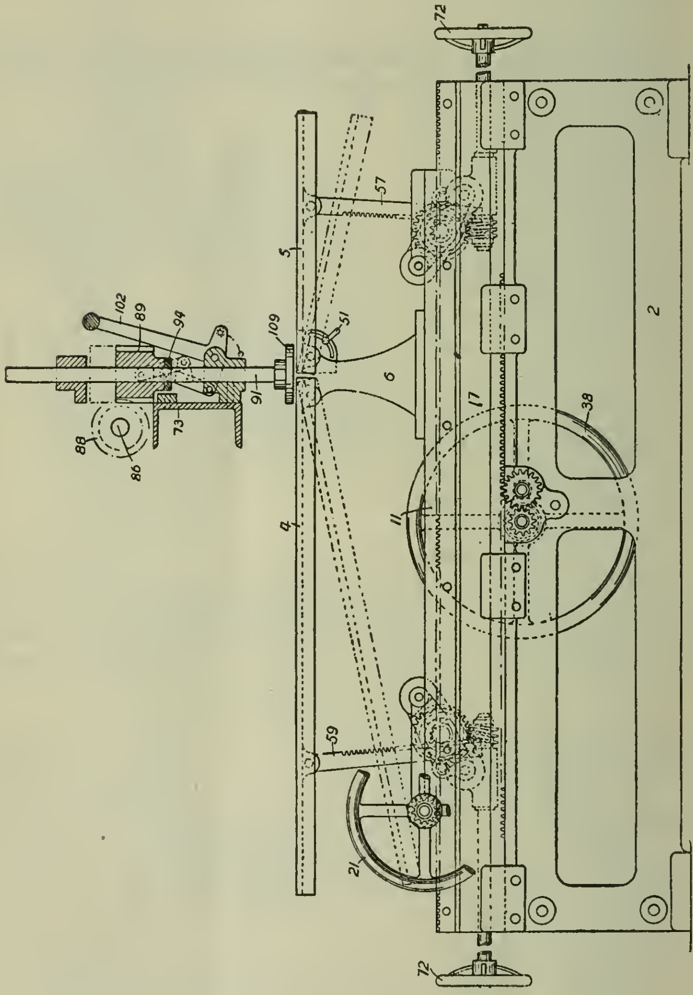


Fig. 146.

the spindles. The tools may be of disk or of hour-glass shape, and, for the supply of the abrading material, they may be formed with annular gutters communicating by passages with the working faces. H. G. C.

287. Grinding and Polishing. C. ZEISS, GERMANY (Brit. Pat. No. **115632**, April 25th, 1918, No. 6973. Convention date, May 5th, 1917. Not yet accepted. Abridged as open to inspection under Sec. 91 of the Act).—Disk and wheel apparatus; bevelling. The rims of spectacle glasses, particularly non-circular glasses, the opposite faces of which are dissimilar, are bevelled in the machine shown in plan in Fig. 147. The glass, l^2, is mounted on the end of a spindle, l, which carries a former disk, l^3, working against a stop-plate, m^1, and runs in a bearing, i, movable in a segmental guideway on the slide, h. The spindle is driven by an electric motor, k, on the bearing, i, and the bearing may be swung round on the segmental guideway to bevel first one edge of the glass and then the other. The slide, h, is drawn towards the grinding wheel, g^4, by weighted cords, n, and the line of its movement forms an angle differing from a right angle with the axis of the spindle. The stop-plate is set at an angle which is adjustable; it is movable along a guideway into the position shown in dotted lines for bevelling the second edge of the glass. By fixing the former disk, l^3, to the bearing, i, the machine may be used for bevelling circular glasses. H. G. C.

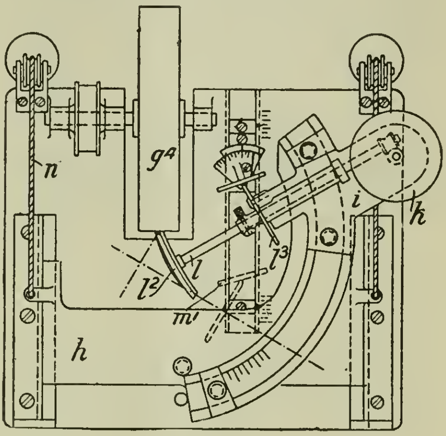


FIG. 147.

288. Grinding Lenses, etc. W. TAYLOR (Brit. Pat. No. **116397**, July 21st, 1917, No. 10507).—Lenses which have been rough ground are smoothed by a lap shaped to fit the curve of the lenses, the lap and the lens-holder being mounted upon spindles arranged at an angle to one another. The lap is adapted to seat itself upon the lenses without constraint, except that due to the feeding force, which is in the direction of the axis of the lap. The detritus is washed away continuously by a supply of water, and the smoothing abrasive may be supplied in suspension in the water or may be fixed in the lap. The lap, D, is mounted upon a hollow spindle, C, mounted in fixed bearings, $C1$, $C2$, and rotated by the pulley, C^4. The liquid, or liquid and abrasive, are supplied through the hollow spindle, and are led through grooves, I, in the lap surface, or through the spaces between a number of lenses, to all parts of the surface to wash away the detritus. The grooves in the face of the lap are arranged in such a manner that the liquid has to traverse substantially the whole of them before it escapes. The lens or lenses, $F4$, $F5$, are mounted on a holder, $F2$, secured by a chuck, $F3$, to a spindle, F, carried in a frame, $F1$. The frame is secured to a bar, $F6$, mounted to slide in the direction of the axis of the lap spindle, C, in bearings, $F7$, $F8$, and is counterweighted. The spindle, F, is driven by a belt, G, passing round guide-pulleys, $G1$, $G2$, on a fixed bracket, and a pulley, $F11$, on the spindle. A strut is interposed between the frame, $F1$, and the axle carrying the pulleys, $G1$, $G2$, to take any strain due to the tension in the driving belt and to prevent any constraint being put upon the frame. The spindles are set at an angle to one another—about 20 degrees if the surface to be smoothed is approximately hemispherical—and the feed is obtained by pushing the bar, $F6$, through its bearings. The angle between the spindles may be adjusted by mounting the spindle, F, in a frame carried in circular slides on a part secured to the bar, $F6$. The bearings, $F7$, $F8$, are open at the top and the bottom respectively to allow the bar, $F6$, to be tilted to facilitate attachment or removal of the work. H. G. C.

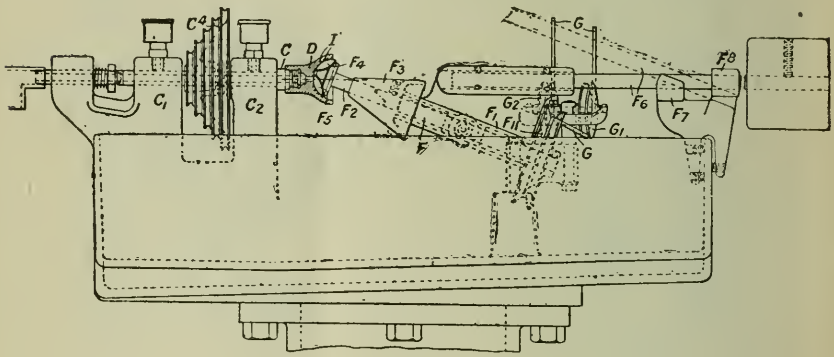


FIG. 148.

I.—Glass-making Materials.

289. Double Salts of Calcium and Potassium and their Occurrence in Leaching Cement Mill Flue Dust. E. ANDERSON (*J. Ind. Eng. Chem.*, 1919, **11**, 327).—Owing to the recent development of the cement potash industry, attention had been directed to certain double salts of potassium and calcium. Of these, *syngenite*, or potassium mono-calcium sulphate,

$$K_2SO_4,CaSO_4,4H_2O,$$

was perhaps the most familiar, but potassium penta-calcium sulphate, $K_2SO_4,5CaSO_4,H_2O$, was equally important. These salts occurred in natural potash deposits, and the fact that they could be easily made artificially indicated the possibility of the formation of such compounds in solution from potash-bearing flue dust, since calcium sulphate was often found in such dust.

The author gave a *résumé* of the data already available concerning these compounds, and discussed the possibility of their production by leaching cement mill flue dust. C. M. M.

290. Some Chemical Aspects of the Potash Industry in Great Britain. E. C. ROSSITER and C. S. DINGLEY (*J. Soc. Chem. Ind.*, 1919, **38**, 375T).—An account was given of investigations regarding the possibility of potash production from blast furnaces. The sources considered were the raw materials used in the blast-furnace charge, the flue dust, and the blast-furnace products. Unless the addition of salt to the charge was made and efficient methods of cleaning the flue gases were used, it was improbable that potash recovery could be made profitable.

The limestones and cokes did not, as a rule, contain more than 0·1 per cent. of potash calculated as KCl, the chief source of potash being the iron ore. Of the ores examined, the following particulars were given:—

Ores.	Percentage content K_2O.
Ferro-manganese (7 samples)	0·526
Northamptonshire (37 samples)	0·420
Cleveland (13 samples)	0·366
North Lincolnshire (13 samples)	0·358
Oxfordshire (4 samples)	0·303
Foreign (22 samples)	0·158
North-west coast (18 samples)	0·153

A clean ore contained less potash than an ore not clean; hæmatite iron ore contained less potash than inferior ore. Strata adjacent to certain ores often contained a higher percentage of potash than the ore itself. The sand next the ore at Scunthorpe, for example, contained potassium compounds amounting to 1·5 per cent. calculated as KCl. The possible potash production per ton of pig iron from ores was given as follows:—

Ores.	Pounds KCl.
Ferro-manganese	37
Northamptonshire	38·5
Cleveland	46
North Lincolnshire	49
Foreign	10
North-west coast	10·5

The flue dust from blast furnaces could be used directly as a fertiliser. The heavy dust contained little potash, but the soluble potash content of dust from the stoves and boiler settings varied from 3 per cent. K_2SO_4 with 4 per cent. KCl to 30·5 per cent. K_2SO_4, and the insoluble potash from 3·6 per cent. to 11·4 per cent. calculated as KCl. The amount of potash obtainable from the dust averaged about 2·5 lb. of KCl per ton of iron, or less than 10 per cent. of the potash contained in the furnace charge, and hence most of the dust could only be suitable for local use as a fertiliser.

The major portion of the potash in the charge came out either in the slag, probably combined as silicates, and in the exit gases, which might contain, after cooling, potassium as carbonate, bicarbonate, formate, cyanide, thiocyanate, sulphate, and chloride, with small quantities of bromides and iodides. Only the potash in the gases was available for the manufacture of potassium salts, and it was essential that as much potash as possible should be present in the gases and as little as possible in the slag. A highly basic charge treated in the furnace at high temperatures would suffer volatilisation of the whole of the potash. The addition of salt to the furnace charge was found to increase the volatilisation of the potash, and as much as 80 per cent. was recovered in certain cases. The authors estimated that potassium salts equivalent to 60,000 or even 80,000 tons of potassium chloride per annum were recoverable from the blast furnaces of England and Wales, an amount approximately double the pre-war consumption of this country.

Thirteen tables of detailed data relating to potash recovery from blast furnaces were also given. F. W. H.

II.—Glass: Manufacture and Properties.

291. Yellow Glass Produced by Coal. L. Springer (*Sprechsaal*, 1919, **52**, 88).—The production of a yellow colour in glass by carbon is already well known, the use of coke, anthracite, graphite, and carbonaceous substances for the purpose being common. Antique glasses of a yellow or brown colour are known in which heavy metals are absent, so that carbon must be the responsible colouring agent in some form, in conjunction with sulphate-containing impurities. Kunkel appeared to be the first to recognise that the direct addition of carbon to the glass batch produced a yellow glass. At first the view held was that the carbon itself produced the colour. Splitgerber, however, in 1839 recognised that glass coloured yellow by carbon also contained sulphur, and showed that with two carbon-containing batches, one with 1·75 per cent. of sodium sulphate and the other without any, only the former developed a yellow colour. Pelouze in 1865, who independently discovered the same fact, found also that other substances, such as sulphur, silicon, boron, and phosphorus, which had the power of reducing sulphates, gave rise to a yellow colour. Further, hydrogen at incipient red heat produced a similar colour with sulphate-containing glass, whilst selenium gave colours analogous to sulphur.

From these facts, the author stated, a general belief had arisen that carbon alone, without sulphur-containing materials, could not give rise to a yellow colour in glass, and in support of this view he quoted statements by Dralle, Schnurpfeil, Hohlbaum, and Müller. The author shared this view until some experiments with graphite added to batch materials of high quality led him to doubt its validity. Hence a series of tests was undertaken with purified batch materials melted in small covered crucibles with the object of excluding possible sulphur dioxide arising from the coke-fired furnace employed. The following mixtures were tested:—

1. Sand 100, soda 30, potash 30, calcium carbonate 20, together with (*a*) 0·7 graphite in one test, and (*b*) 0·3 graphite in a second. With (*a*) the glass was a yellowish-brown; (*b*) bright yellow.

2. (*a*) as in 1 (*a*), but with 2·1 parts of powdered brown coal. Again a bright yellow colour was obtained.

(*b*) as in (1), but 60 soda instead of 30 soda and 30 potash, and 2·1 parts of powdered coke. The coke appeared to have sunk to the bottom, since the upper portion of the glass was almost colourless, but the lower was yellow.

(*c*) as in (1), but using 60 parts commercial soda containing approximately 6 per cent. of sodium sulphate. The glass was yellowish-brown in colour.

Five further series of experiments on very similar lines were carried out to test the effect of different forms of carbon, soot, and sugar-charcoal, of sulphate-free mixtures of soda and lime, of the addition of sulphate, and of the effect of using all potash instead of soda. The general conclusion was that carbon alone has the power of imparting a yellow colour, even in the absence of sulphur-containing substances, although the presence of the latter may emphasise the colour.

Samples of the glass coloured by carbon were treated by hydrofluoric acid, and a black deposit of insoluble carbon obtained. One sample, for the preparation of which 2·67 per cent. of carbon had been used in the batch, contained approximately 1 per cent., the remainder having obviously been volatilised after oxidation. The author expressed the view that the yellow colour imparted by carbon is due to the presence of the latter in the colloidal condition.

W. E. S. T.

292. Experiments on Barium Glasses. H. Fritz (*Sprechsaal*, 1918, **51**, 51).—A series of tests carried out to determine the mixtures of baryta, silica, alumina, zinc oxide, and the alkalis with which ready melting could be accomplished at a temperature SK $4a-6a$ (1160—1200°) in small crucibles. The alumina was added as kaolin or, where practicable, as felspar.

No fusion was found possible with baryta and silica mixtures between BaO,SiO_2 and $BaO,6SiO_2$. On the introduction of alumina, also, the following mixtures remained completely unmelted: $BaO,0{\cdot}1Al_2O_3,SiO_2$ to $BaO,0{\cdot}6Al_2O_3,6SiO_2$ and

$$BaO,0{\cdot}1Al_2O_3,2SiO_2 \text{ to } BaO,0{\cdot}6Al_2O_3,7SiO_2,$$

the alumina being increased in each case by 0·1 molecule at each stage and the silica by 1·0 molecule.

4-27-20

Potash was next added to the baryta, alumina, silica mixtures in such a manner as to replace the baryta in stages of 0·1 molecule K_2O for 0·1 BaO. The compositions ranged from

$$\left.\begin{matrix}0{\cdot}1K_2O\\0{\cdot}9BaO\end{matrix}\right\}0{\cdot}1Al_2O_3,2SiO_2 \text{ to } \left.\begin{matrix}0{\cdot}3K_2O\\0{\cdot}7BaO\end{matrix}\right\}0{\cdot}6Al_2O_3,7SiO_2.$$

In all these cases sintering occurred, but not fusion.

On the addition of zinc oxide, replacing baryta to a certain degree, melting occurred in most cases with production of a clear glass. The mixtures which melted were:

$$\left.\begin{matrix}0{\cdot}1K_2O\\0{\cdot}2ZnO\\0{\cdot}7BaO\end{matrix}\right\}0{\cdot}1Al_2O_3,2SiO_2 \qquad \left.\begin{matrix}0{\cdot}2K_2O\\0{\cdot}1ZnO\\0{\cdot}7BaO\end{matrix}\right\}0{\cdot}2Al_2O_3,3SiO_2$$

$$\left.\begin{matrix}0{\cdot}2K_2O\\0{\cdot}1ZnO\\0{\cdot}7BaO\end{matrix}\right\}0{\cdot}2Al_2O_3,2SiO_2 \qquad \left.\begin{matrix}0{\cdot}1K_2O\\0{\cdot}3ZnO\\0{\cdot}6BaO\end{matrix}\right\}0{\cdot}2Al_2O_3,2{\cdot}5SiO_2$$

$$\left.\begin{matrix}0{\cdot}15K_2O\\0{\cdot}15ZnO\\0{\cdot}7BaO\end{matrix}\right\}0{\cdot}2Al_2O_3,2{\cdot}5SiO_2 \qquad \left.\begin{matrix}0{\cdot}2K_2O\\0{\cdot}2ZnO\\0{\cdot}6BaO\end{matrix}\right\}0{\cdot}2Al_2O_3,2{\cdot}5SiO_2.$$

A mixture containing

$$\left.\begin{matrix}0{\cdot}3K_2O\\0{\cdot}2ZnO\\0{\cdot}5BaO\end{matrix}\right\}0{\cdot}2Al_2O_3,2{\cdot}5SiO_2$$

did not melt satisfactorily.

The author stated that the glasses produced had a bright blue colour.

W. E. S. T.

293. Behaviour of an Acid Glass in a Tank Furnace. J. M. Knote (*Trans. Amer. Cer. Soc.*, 1912, **14**, 655).—The author described a case of devitrification of glass resulting in machine-made bottles exhibiting white streaks. These tails represented the glass adhering to the dipping rod after cutting off the metal for the previous bottle, the residue of one not blending perfectly with the next gathering of glass.

The trouble developed most in machines making large bottles. On a furnace delivering 12 tons per day, it was reduced by an increase in the gas pressure. A smaller furnace, delivering 8 tons, gave no trouble, and samples of glass taken from the two tanks had the following percentage composition:—

		Small tank.	Large tank.	Empirical molecular formula.	
Glass I.	Silica	77·0	77·3	Magnesia ... 0·2	Silica 3·13
	Lime	4·62	4·52	Lime ...... 0·2	
	Magnesia	3·26	3·24	Soda ...... 0·6	
	Soda	15·10	15·94		

A three-year-old bottle had the following composition, II, whilst the glass made at another factory the results under III:—

Glass II.		Glass III.	
Silica	76·45	Silica	73·10
Lime	4·05	Lime	13·47
Magnesia	2·80	Magnesia	0·5
Soda	16·7	Soda	12·1

In discussing this trouble, Dr. Tillotson pointed out that a glass may be quickly cooled below its melting point without devitrifying, but on reheating to the softening point crystallisation might take place, causing the glass on the dipping rod to devitrify. The temperature attained during the melting and fining of the glass was a very important factor, and as the trouble was absent from the small furnace or when using higher gas pressure, a greater degree of chemical equilibrium and physical homogeneity were doubtless obtained, due to higher temperature.

Denoting the alkaline earth oxides by RO and the oxides of the alkalies by R_2O, glasses I and III may be expressed as:—

$$\text{I. } (RO,SiO_2) + 1{\cdot}49(R_2O,\ 4{\cdot}55SiO_2).$$
$$\text{III. } (RO,SiO_2) + 0{\cdot}77(R_2O,\ 5{\cdot}36SiO_2).$$

The ratios 1·49 and 0·77, representing $\frac{\text{equiv. } R_2O}{\text{equiv. } RO}$ were important in determining the physical properties of a glass, especially devitrification. The ratios 4·55 and 5·36, indices of the "acidity" of the glass, showed, in this case, that a glass with a lower percentage of SiO_2 might yet be the more "acid" glass.

Mr. Gelstharp expressed the view that, in using soda ash alone as the source of alkali, there was a minimum limit for the ratio of soda to lime and magnesia if a white scum or devitrification was to be avoided. This limit was near 2:1, that is,

$$Na_2O : CaO + MgO :: 2 : 1,$$

and the empirical formula of this glass would be

$$\left.\begin{array}{ll}\left.\begin{array}{r}\mathrm{CaO}\\\mathrm{MgO}\end{array}\right\} & 0{\cdot}33\\ \mathrm{Na_2O} & 0{\cdot}66\end{array}\right\} \mathrm{SiO_2X}.$$

In glass I the ratio $\frac{Na_2O}{CaO + MgO} = \frac{1{\cdot}5}{1}$ and this glass, in his opinion, favoured devitrification under suitable conditions.

For glass II the ratio was 1·95 : 1, and this agreed with the desired ratio, 2 : 1, mentioned above, and this glass did not devitrify. Even after consideration of these ratios, trouble was likely to arise if a change occurred in the composition of the materials used, especially if burnt lime were used instead of limestone, or if dolomitic lime be used.

Using a properly proportioned glass, the reheating of the glass on the rod would only produce a cord at the worst. V. D.

294. Some Chemical Reactions of Interest to the Plate Glass Chemist. F. Gelstharp (*Trans. Amer. Cer. Soc.*, 1912, **14**, 642; 1913, **15**, 585).—A study of the properties of the raw materials concerned and of their reactions with one another. The main conclusions were:—

(1) *Saltcake* begins to dissociate at about 1300°, and the rate of dissociation increases rapidly with rise in temperature.

(2) *Sand + Soda Ash.*—In a mixture of soda ash and excess of sand, either Na_2O,SiO_2 or $Na_2O,2SiO_2$, or a mixture of these, might be found depending on the intimacy of the sand and ash mixture. The disilicate would predominate, and on continued heating the silicates would dissolve the excess of sand.

(3) *Sand + Saltcake.*—Na_2SO_4 (saltcake) begins to react with silica near its melting point, and the rate of the reaction depends on the temperature.

(4) *Sand + Common Salt.*—Using rather damp, coarse-grained salt and sand passing a 40-mesh sieve, but the bulk remaining on a 60-mesh, the proportions being 120 sand to 61·5 salt, and heating ultimately to 1400°, it was found that 1·92 grams of salt reacted with 100 of SiO_2. The author believed the first of the following reactions to be the more probable, the sand grains becoming coated with silicate of soda in the presence of water vapour, and this surface film preventing further reaction:—

$$2NaCl + 2SiO_2 + H_2O = Na_2O.2SiO_2 + 2HCl,$$
$$4NaCl + 5SiO_2 = 2(Na_2O,2SiO_2) + SiCl_4.$$

(5) *Saltcake + Limestone.*—According to the author, no reaction took place on heating to 1000°.

(6) *Sand + Saltcake + Charcoal.*—Used in correct proportions, sodium silicate was obtained thus:—

$$2Na_2SO_4 + C + 4SiO_2 = 2(Na_2O,2SiO_2) + 2SO_2 + CO_2,$$

but if the C be in excess, some sodium sulphide may be produced, according to the reaction

$$Na_2SO_4 + 2C = Na_2S + 2CO_2.$$

This reaction might be more complex, and a polysulphide of sodium being formed, colouring the sodium silicate yellow. Such a reaction would occur as follows:—

$$2NaSO_4 + 4C = Na_2CO_3 + Na_2S_2 + 2CO_2 + CO,$$

the Na_2CO_3 forming sodium silicate, which dissolves the polysulphide. A silicate had actually been obtained which, when dissolved in hydrofluoric acid, liberated free sulphur with evolution of H_2S.

(7) *Sand + Soda Ash + Saltcake + Common Salt + Limestone + Charcoal + White Arsenic.*—In proper proportions and intimately mixed, a homogeneous glass should be produced, the reactions usually being expressed as:—

(*a*) $Na_2CO_3 + nSiO_2 = Na_2O,nSiO_2 + CO_2$.
(*b*) $CaCO_3 + 2SiO_2 = CaO,2SiO_2 + CO_2$.
(*c*) $2Na_2SO_4 + C + 2SiO_2 = 2(Na_2O,2SiO_2) + 2SO_2 + CO_2$.
(*d*) $2NaCl + H_2O + SiO_2 = Na_2O,SiO_2 + 2HCl$.
(*e*) As_2O_3 might oxidise iron, and the resulting arsenic and residual white arsenic would volatilise.

These equations failed to explain many phenomena which arose in glass making. For instance, CaS might be formed to some extent, as in the old Le Blanc soda process, and this, along with possible Na_2S, Na_2S_2, and impurities such as Fe_2O_3, Al_2O_3, and $CaSO_4$ complicated the reactions.

The presence of SiO_2 lowered the temperature of complete decomposition of $CaSO_4$, and the reaction between $CaSO_4$ and SiO_2 took place more rapidly than the one between Na_2SO_4 and SiO_2. $CaSO_4$ reacted with charcoal according to the following equations (H. O. Hofman and W. Mostowitsch, *Bull. Amer. Inst. Min. Eng.*, **47**, 917):—

(1) $CaSO_4 + 4C = CaS + 4CO$, commencing at 700° and complete at 1000°. Below 800° CO_2 was formed, but above 800° CO, the CO reducing $CaSO_4$ more readily than C.

(2) $CaSO_4 + 4CO = CaS + 4CO_2$, commencing at 680° and complete at 800°.

(3) $3CaSO_4 + CaS = 4CaO + 4SO_2$, beginning at 800° and energetic between 850° and 900°.

Ground glass, mixed with $CaSO_4$ and maintained at 1370°, showed that CaO was taken up by the glass, Na_2SO_4 separating on the surface, disappearing later by dissociation, part of the Na_2O being again taken up by the glass. All attempts to reduce Na_2SO_4 to Na_2SO_3 by C were unsuccessful.

(8) *Soda Ash + White Arsenic.*—Usually in a glass batch As_2O_3 was stated to act thus:—

$$5As_2O_3 = 3As_2O_5 + 2As_2.$$

The metallic As passed off, and As_2O_5 oxidised the materials, being reduced to As_2O_3, the process being repeated until all the As has left the glass. However, from his experiments, the author believed the As_2O_3 to exert a reducing action, thus:—

$$As_2O_3 + 3Na_2CO_3 + O_2 = 2Na_3AsO_4 + 3CO_2.$$

This view was supported by the use of the oxide to remove black streaks in glass. The glass became seedy and green, due to the reducing action of the arsenic compound.

(9) *Saltcake + White Arsenic.*—After heating to 940°, the product was found to be neutral to litmus and contained As_2O_5. Sulphur compounds were absent, but if formed by the reduction of the Na_2SO_4, they would be immediately oxidised, leaving Na_3AsO_4. Later, Na_3AsO_4 was found to produce no decomposition of Na_2SO_4, probably because here the arsenic was not capable of further oxidation, but when Na_3AsO_3 was heated to 940° in a closed crucible with Na_2SO_4, a decided action took place, sulphur compounds being produced, whilst the melt was strongly alkaline and brownish in colour. Treatment with acid precipitated sulphide of arsenic, and H_2S was liberated. Hence sodium sulphides, with sodium arsenate and sulpharsenate, must have been formed.

(10) *Limestone + White Arsenic.*—The experiments indicated that the reactions with $CaCO_3$ and CaO proceeded as follows when heated to 1090°:—

$$3CaCO_3 + As_2O_3 + O_2 = Ca_3(AsO_4)_2 + 3CO_2,$$
$$3CaO + As_2O_3 + O_2 = Ca_3(AsO_4)_2.$$

As_2O_3 in a glass batch was partly reduced by carbon, but the author had found as much as 56 per cent. of the original oxide left in the finished plate glass, not as As_2O_3, but as As_2O_5. Hence As_2O_3 acted as a reducing agent, and although volatile at 200—250°, it remained in the melt by combining with Na_2O or CaO, forming comparatively stable arsenates.

(11) *Sand + Soda Ash + Limestone.*—The results showed that when the ratio of Na_2O to CaO was less than 2 : 1, a uniform glass was not likely to be obtained. The thick, white scum which remained on the surface of the pot during the experiments, using the materials in varying proportions, was found to be a crystallised double silicate approximating to the composition:—

Na_2O.	CaO.	SiO_2.
0·585	0·415	5·100

$$\begin{matrix}(Na_2O,8SiO_2)\\ 2CaO,3SiO_2\end{matrix} \text{ or } 3Na_2O,2CaO,27SiO_2.$$

The addition of a little Na_2SO_4 decomposed it, and it became incorporated in the melt.

In conclusion, the author stated that he found in all cases considered that As_2O_3 acted as a reducing agent, and he failed to find Na_2SO_3 present in melting a glass batch. V. D.

295. Opal and Green Glasses. (*Sprechsaal*, 1906, **39**, 645).—The following formulæ for green and opal glasses which could be joined together were stated:—

Opal.

	I.	II.	III.
Sand	93 kg.	85 kg.	100 kg.
Soda	25	24	15
Cryolite	12	10	15
Lime	5	—	10
Fluorspar	5	10	—
Felspar	6	28	—
Saltpetre	1	500 gr.	5
Manganese oxide	200 gr.	100 ,,	—
Nickel oxide	4 ,,	3 ,,	—
Potash	—	3 kg.	10

Green.

	I.	II.	III.
Sand	42·5 kg.	55 kg.	100 kg.
Potash	5	20	12·5
Soda	10	—	20
Lime	5	7·5	15
Saltpetre	0·5	—	—
Red lead	1	7·5	—
Borax	500 gr.	—	—
Uranium oxide	375 ,,	—	—
Copper oxide	1,000 ,,	1·25	5
Chromic oxide	1,000 ,,	—	—
Potassium bichromate	—	1·5	0·5
Ferric oxide	—	—	2

J. R. C.

296. Emerald Green Glass. (*Sprechsaal*, 1906, **39**, 473).—The following batches were recommended for emerald green glass:—

	I.	II.	III.	IV.
Sand	100 kg.	100 kg.	100 kg.	75 kg.
Soda	20	5	22	15
Potash	10	35	10	19
Borax	3	3	3—4	—
Saltpetre	6	—	2	—
Lime	20	22	18	12
Potassium bichromate	1	0·5	1	0·35
Copper oxide	300 gr.	—	0·1	0·35
Iron oxide	200 ,,	—	—	—
Uranium oxide	—	1·3	—	0·03
Copper sulphate	—	5	—	—
Antimony oxide	—	—	0·25	—

J. R. C.

297. Solubility of some Salts in Glass. F. Gelstharp (*Trans. Amer. Cer. Soc.*, 1912, **14**, 665).—In the author's view the following reactions may take place under the conditions of glass melting:—

$$2Na_2SO_4 + 4SiO_2 + C = 2(Na_2O,2SiO_2) + CO_2 + 2SO_2,$$
$$2Na_2SO_4 + 4SiO_2 = 2(Na_2O,2SiO_2) + 2SO_2 + O_2,$$

or simple dissociation might occur at the fining temperature,

$$2Na_2SO_4 = 2Na_2O + 2SO_2 + O_2,$$

some of the alkali being volatilised and some absorbed by the glass. The decomposition of NaCl might also proceed, to some extent, according to the following equation:—

$$2NaCl + 2SiO_2 + H_2O = Na_2O,2SiO_2 + 2HCl,$$

and any remaining NaCl would be volatilised, since the fining temperature of glass is about 530° above the volatilising temperature of the chloride.

Careful chemical analyses were made of plate glass made from SiO_2, Na_2SO_4, Na_2CO_3, NaCl, $CaCO_3$, C, and As_2O_3. Although, according to the above reactions, no Na_2SO_4 or NaCl would be expected in the finished glass, yet they were both found present to a considerable extent.

Na_2SO_4 was found in varying amounts, ranging from 0·59 to 1·74 per cent. in different samples of plate glass. The absorption of SO_3 from furnace gases during melting would produce Na_2SO_4 in a glass otherwise not containing the salt, but in glasses made and tested under the same conditions this did not amount to more than 0·22 per cent.

NaCl was found present in samples to the extent of 0·91 to 1·48 per cent., while two samples tested for both sulphate and chloride contained:—(1) Na_2SO_4 0·85 per cent., NaCl 0·91 per cent.; (2) Na_2SO_4 0·64 per cent., NaCl 1·48 per cent.

Increase of temperature or increase of time at the same temperature caused a decrease in the amount of Na_2SO_4 present, and glass containing much NaCl continued to give off NaCl vapours.

The maximum amount of these two salts that could be retained by plate glass depended largely on the time of exposure to certain temperatures, but at the ordinary fining temperature the author found the maximum of Na_2SO_4 to be 1·74 per cent., while that of NaCl was 1·48 per cent. According to the author, plate glass containing these salts was less soluble in water than that not containing them, indicating that solubility depends on percentage of alkali silicate.

The depth of colour of opal glass depended largely on the solubility of fluorides in it, long-continued heating driving off most of the dissolved fluoride.

Large quantities of CaS or Na_2S might be retained by glass, but it was not clear whether such were cases of solubility, or chemical combination, or simple mixture.

The following method was used by the author for the estimation of SO_3 or Na_2SO_4. Fuse 1 to 2 grams of the finely ground sample with Na_2CO_3 in a platinum crucible over an alcohol blast lamp. Digest the fused mass with water, and make slightly acid with HCl. Boil well, and add a small quantity of paper pulp. Filter off the SiO_2, using a filter pump. To the boiling solution add just sufficient $BaCl_2$ for precipitation; boil for some time. Filter off the $BaSO_4$, which contains some SiO_2. Burn the filter paper at a low temperature. Treat the residue in the platinum crucible with HF and a few drops of H_2SO_4. Heat to drive off SiF_4 and the excess of H_2SO_4. Fuse the residue with Na_2CO_3, take up with water, add a drop of HCl in excess in order to make the liquid acid, and boil for some time. Filter and weigh the $BaSO_4$, and calculate from it the percentage of SO_3 or Na_2SO_4. V. D.

298. An Investigation of the Surface Devitrification of Glasses under Thermal After-treatment. C. J. BROCKBANK (*Trans. Amer. Cer. Soc.*, 1913, **15**, 600).—The author described experiments made to determine the influence of chemical composition of a glass on its susceptibility to surface devitrification, and also the critical temperature required to induce the change rapidly. The soda-lime–silicates were studied, and melts of 5 lb. and 1500 lb. were made. The temperature probably reached 1600° on heating, and, after twelve hours' cooling, test-pieces of glass were ground and polished for experiment.

These pieces were heated in a gas muffle, and the softening and "dimming" temperatures determined by the aid of the reflections in the glass surface of a small steel rod, its point resting on the surface, the temperatures being recorded by a thermocouple. Care was taken to maintain uniform time of reheating in each case.

Details of the melts and temperatures were given, and the following conclusions were drawn from the results:—

(1) Substitution of potassium carbonate for sodium carbonate raised the dimming point and increased chemical and physical stability.

(2) Boric acid produced no marked improvement.

(3) Introduction of magnesia, and particularly alumina, into white sheet glass was very beneficial, making the glass more stable.

(4) The use of dolomite, particularly in conjunction with alumina, resulted in great improvement, even if the glass were more difficult to "fine."

(5) In flint glasses the substitution of soda for potash was detrimental, but a mixture of the two was still more so. V. D.

299. Note on the Solubility of Zinc Oxide in Fused Lead Silicate and Borate. A. D. HOLDCROFT (*Trans. Eng. Cer. Soc.* 1909–10, **9**, 37).—The author first proved that there was practically no volatilisation of lead from the lead silicate at the temperature at which the experiments were made. The objects of further experiments were: (1) to determine the solubility of zinc oxide in lead monosilicate at 1000°. (2) To compare the solubility of zinc oxide with that of zinc silicate and willemite (natural zinc silicate) at 1000°. (3) To ascertain the solubility of zinc oxide in PbO,SiO_2 at 850° and in PbO,B_2O_3 at 1000° and 850°. The author gives the conclusions as follows:—

Grams of zinc oxide soluble in	1000°.	850°.
PbO,SiO_2	13—14	7—10
PbO,B_2O_3	60—70	50—60

These results may be of use in the making of crystalline glazes, using zinc oxide. C. M. M.

300. The Volatilisation of Lead Oxide from Lead Silicate Melts. OLAF ANDERSEN (*J. Amer. Cer. Soc.*, 1919, **2**, 784).—The author made experiments on the amount of PbO volatilised from the surface of lead silicate glasses at temperatures from 900° to 1400°. The experiments were carried out in an electric furnace, and the losses were obtained by weighing the crucible at the beginning and at the close of the experiment. It was found that the rate of loss decreased with prolonged heating, but remained constant when stirring was applied, the reduction in loss from the unstirred samples being due undoubtedly to the formation of a surface layer relatively richer in silica. The results are tabulated as follows:

Volatilisation of PbO *from Pure Lead Silicate Glasses.*
Loss in mg. per sq. cm. per hour.

Percentage of PbO in glass	85	78·7	75	70	65	60
Temperature :—						
1400°	318	131	91	60	46	33
1300	100	40	30	23	16	13
1200	37	11	8	7	5	4
1100	13	4	2	2	1	1
1000	8	2	1	1	—	—
900	1	1	—	—	—	—

It was found that the volatilisation from an unstirred glass in fifteen minutes occurred at approximately the same rate as from a stirred glass heated for a longer period of time. The above results are based on a short heating without stirring of melt. Further, the author states that if the procedure is reasonably constant from melt to melt, variations in refractive index due to volatilisation are not to be expected; but if the melting schedule be changed the volatilisation may be large enough to cause considerable variations in refractive index. C. M. M.

301. A Thermal Study of Boric Acid–Silica Mixtures. A. V. BLEININGER and P. TEETOR (*Trans. Amer. Cer. Soc.*, 1912, **14**, 210).—Mixtures of silica and boric acid possessed the character of glasses or solid solutions, and their thermal study might indicate any possible chemical combination. The research dealt with (*a*) the determination of softening points of mixtures between the limits B_2O_3—$B_2O_3,3SiO_2$, (*b*) the determination of heating and cooling curves, and (*c*) an investigation of the solubility of the fused glasses in water. The reagents used were chemically pure hydrous boric acid and silica, and some fusions were made, using flint which passed a 200-mesh sieve.

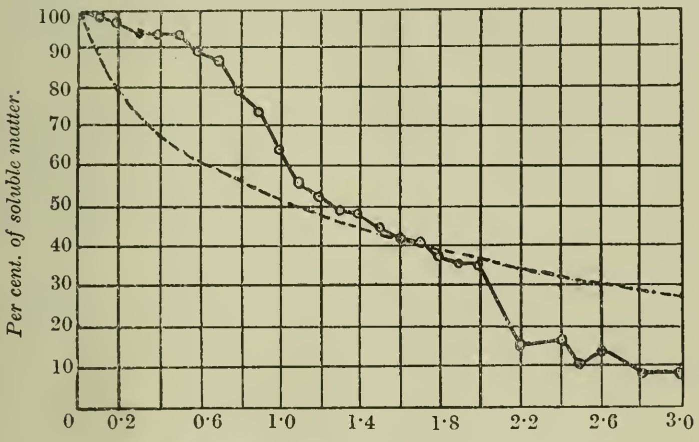
In determining the softening points, the fused mixtures were ground to fine powders, made into cones with a little water, placed in an electric resistance furnace, and the temperature at which the cones bent was measured.

The deformation point of B_2O_3 was difficult to determine, due to evolution of steam, some anhydrous boric acid reverting to the hydrous form. The addition of $0·1SiO_2$ made the cones stand in good shape. The addition of water to the mixture $B_2O_3,1{\cdot}5SiO_2$ resulted in considerable heat being given off, but little was evolved by $B_2O_3,1{\cdot}4SiO_2$ and the mixture $B_2O_3,1{\cdot}6SiO_2$. The mixture $B_2O_3,1{\cdot}5SiO_2$ became pink on fusing.

The glasses were quite viscous, and on repeating the tests the results varied, more beyond $B_2O_3,2SiO_2$ than below, and even more varied were the results obtained by using rods drawn from the fusions. The internal molecular friction would retard any reaction taking place in these mixtures, which were typical glasses, having no definite deformation temperatures.

In the determination of the heating and cooling curves no temperature acceleration or lag was observed.

In order to investigate the solubility of the mixtures in water, they were pulverised, and the portion passing the 80- but remaining on the 150-mesh sieve, was used. Samples were shaken in distilled water for ten hours, allowed to stand overnight, then the residue was filtered and washed, dried, ignited, and weighed.



Molecular equivalents SiO_2 *to* $1B_2O_3$.

FIG. 149.

The results are set out in Fig. 149, from which it is seen that in the lower part of the series all the boric acid, and some silica, were dissolved, but at about the composition $B_2O_3,1{\cdot}8SiO_2$ some B_2O_3 had become insoluble. The amount of soluble matter decreased more rapidly than the B_2O_3 content, and between 2 and $2{\cdot}2SiO_2$ a decided fall in solubility indicated that a chemical combination might have taken place at this point, and the formation of some of this compound earlier in the series might explain the gradual decrease in solubility that was found. V. D.

302. Some Chemical Characters of Borate Glasses. BURGESS and HOLT (*Trans. Eng. Cer. Soc.*, 1905–6, **5**, 163).—The addition of a metallic oxide to fused boric anhydride results in one of three things: (1) the oxide is insoluble, (2) or it forms an almost insoluble borate; (3) or it forms a soluble borate. The first case included the oxides of gold, the platinum metals, and probably the oxides of aluminium, tin, thorium, and other rare earths. The oxides of gold and platinum were decomposed, the finely divided metal being suspended in the fused mass. Lead oxide, though forming a borate, was easily reduced, rendering the mass opaque.

In the second case studied by Guertler (*Zeitsch. anorg. Chem.*, 1902, **40**, 225, 268, 337) the anhydride dissolved a little of the borate, and the borate dissolved some 3 or 4 per cent. of the anhydride, so that, if only a little of the oxide were used, two non-miscible liquids were formed. The resulting mass presented a milky appearance when a very small quantity of oxide was used, and further addition of the oxide produced a clear, homogeneous glass consisting of the most acid borate; but later an opaque mass was formed.

The oxides of the alkalies and thallium constituted case (3), though the behaviour of arsenic, antimony, and mercury was uncertain. Results of previous work on mixtures of sodium carbonate and boric anhydride were referred to, and it appeared that some of these mixtures formed a less fusible, crystalline modification when heated for some time at a temperature just below their melting points.

Mixtures containing boric anhydride and sodium oxide in the ratio 8 : 5, or with the anhydride in greater proportion, were glasses, while a greater oxide content produced crystalline substances, which could only be obtained as glasses by sudden cooling. Glasses could not be obtained at all if the ratio B_2O_3 : Na_2O was less than 2 : 3. Glasses that were prepared with difficulty could easily be devitrified, one of composition $3Na_2O,2B_2O_3$ devitrifying when heated in a Bunsen flame, while one of composition $Na_2O,4B_2O_3$ resisted devitrification for days at this temperature. Complete devitrification was impossible when the ratio B_2O_3 : Na_2O exceeded 4 : 1, the crystalline portion of composition $Na_2O,4B_2O_3$ decreasing as the proportion of anhydride increased.

Vitreous and crystalline mixtures of B_2O_3 and Na_2CO_3 consisted of two borates, $Na_2O,4B_2O_3$ and Na_2O,B_2O_3, intermediate crystals being regarded as solid solutions of these two, and mixtures varying from pure B_2O_3 to $Na_2O,4B_2O_3$ were probably solutions of the borate in the anhydride.

Lithium borates gave analogous results, but only one compound, $Li_2O,2B_2O_3$, appeared to be formed. The borates of the alkaline earths formed three distinct compounds.

The colouring properties of the metallic oxides when added to glasses could, according to one theory, be explained by the decomposition of sodium pyroborate into the metaborate, and boric anhydride, the latter combining with the oxide to give a coloured borate:—

$$Na_2B_4O_7 = Na_2O,B_2O_3 + B_2O_3.$$

Since almost all these colouring oxides were insoluble in the anhydride, but dissolved on the addition of alkali, the idea that the oxides acted as an alkali, combining with the excess silica in a glaze, must be discarded. Alkali was essential in coloured glasses, which contained a complex salt of it with the metallic oxide and B_2O_3, as, for instance, sodium–copper borate in copper glass.

Attempts to crystallise cobalt and copper glasses resulted in the separation of almost colourless crystals, with ejection of the colouring matter, showing the glasses to be in a metastable condition. Similarly, the crystallisation of borax, and the separation of some of the dissolved thoria, prevented any regularity in results when attempt was made to determine the amount of ignited thoria that could be dissolved in borax.

The colour imparted to a glaze by an oxide was influenced by the quantity of alkali present; copper oxide imparted a green colour to a borax glass of low sodium content, but the colour changed to blue with increased alkali content. The colour changed, too, with rise in temperature, the change being the inverse of that brought about by an increase of the alkali present, and a comparison with the behaviour of strong aqueous solutions of a copper and cobalt chloride suggested that the colour of the glass might depend on its degree of ionisation.

Boric anhydride did not conduct electricity, but a glass containing a small amount of sodium and copper conducted it readily, the ions produced by the decomposition of the complex sodium–copper borate and the sodium borate carrying the current. If the undissociated molecules were blue, and the ions green, the addition of sodium would cause the glass to appear blue, due to decreased ionisation; and the green colour exhibited at higher temperatures would be due to increased ionisation.

Again, supposing that the complex could combine with more solvent, producing an unstable compound, different in colour, say, blue, then the formation of this blue compound would be helped by the addition of sodium, but at higher temperatures it would give place to the more stable, green compound.

The depression of the melting point of borax by the addition of copper oxide was greatest when one-twelfth equivalent of copper was added; hence an infusible network appeared to be formed by the oxide and copper borates when the glass became saturated. The oxide produced no lowering of the melting point of B_2O_3, as copper borate was insoluble in the anhydride.

The colour of gold and copper ruby glasses was held to be due to entirely different causes. V. D.

303. The Chemical Rôle of Boron in Glazes. R. C. Purdy (*Trans. Amer. Cer. Soc.*, 1912, **14**, 731).—The author reviewed much work previously done on the effect of B_2O_5 on glazes, and questioned the views expressed of similarity in function of Al_2O_3 and B_2O_3.

Evidence showed that in respect to both crazing and devitrification, B_2O_3 and Al_2O_3 had opposite effects in glazes of low oxygen ratio, but the same effect in glazes of higher oxygen ratio; yet this did not prove that in the former case B_2O_3 functioned as an acid and in the latter case as a base.

Studies on colour effects indicated a similarity in action of Al_2O_3 and B_2O_3, but did not prove the actual chemical *rôle* of B_2O_3. V. D.

304. The Thermal Conductivity of some Solid Insulators. W. M. Thornton (*Phil. Mag.*, 1919, **38**, 705).—From inspection of the recorded values of the physical constants of some heat insulators, including glasses, it was observed that the thermal conductivity is equal to the product of the elasticity and density, so that $k = E\rho = V^2\rho^2$, where V is the velocity of sound in the substance. A table of the most probable values of the constants and the products is given, and the very good agreement between k, $E\rho$, and $V^2\rho^2$ indicates that there is some fundamental process, a consequence, possibly, of the electrical structure of matter, beneath these phenomena. As a practical outcome of this relationship, the author holds that a heat insulator should be light and inelastic.

J. R. C.

305. The Spreading of Fluids on Glass. W. B. Hardy (*Phil. Mag.*, 1919, **38**, 49).—When a drop of some fluids is placed on a water surface on which a few dust particles rest, a film of insensible thickness rapidly spreads from it in all directions, pushing the dust particles before it. The drop may then spread to form a layer of sensible thickness. If the fluid is pure, the phenomenon finishes at the first stage. The same was found to hold true for a glass surface, but here the presence of a very small amount of water vapour caused the second stage to take place.

J. R. C.

306. Adsorption of Metals from Drinking Water by Glass. K. Scheringa (*Pharm. Weekblad*, 1919, **56**, 8).—Glass vessels were thoroughly cleaned, and solutions containing known quantities of various salts poured into them. After standing for two days, the metallic content of the solution was determined, and it was found that no diminution had occurred.

Since the proportion of lead in drinking water often decreased in the course of a few hours, it would appear that this decrease was due, not to adsorption by the glass, but to chemical action. The decrease, it was suggested, might be caused by the precipitation of finely divided lead carbonate or by the disturbance of an equilibrium when the water was removed from contact with lead.

F. W. H.

307. Researches in the Chemistry of the Silicates. F. M. Jäger and H. S. van Klooster (*Sprechsaal*, 1919, **52**, 256).—The silicates were prepared by first heating a mixture of quartz and the metal carbonate or oxide to the sintering point in an iridium-

Substance.	Melting point.	Specific gravity.	Observer.	Refractive indices.	Special remarks.
$BeSiO_3$	>1750°	—	Jäger & van Klooster.	—	—
$MgSiO_3$	1554°	3·175	Allen & Wright.	$n_1=1{\cdot}641$; $n_2=1{\cdot}648$; $n_3=1{\cdot}663$.	—
Mg_2SiO_4	1750°	—	—	—	—
$CaSiO_3$	1540°	—	Day, Allen, White, Shepherd & Wright.	$n_1=1{\cdot}609$; $n_2=1{\cdot}650$.	—
Ca_2SiO_4	2130°	3·27	,,	$n_1=1{\cdot}714$; $n_2=1{\cdot}720$; $n_3=1{\cdot}737$.	—
$SrSiO_3$	1578±1°	3·652	Jäger & van Klooster.	$n_1=1{\cdot}620$: $n_2=1{\cdot}590$.	The melt can be supercooled to 1225° when sudden rise of temperature to 1364° accompanied by crystallisation takes place. By rapid cooling of the melt, an almost isotropic glass can be obtained with $n=1{\cdot}618$, spec. gravity 3·540, and by careful heating a micro-crystalline variety is obtained.
Sr_2SiO_4	>1750°	—	,,	—	—
$BaSiO_3$	1604°	4·435	,,	$n_1=1{\cdot}670$; $n_2=1{\cdot}667$.	Small, weakly double refracting crystals. Attempts to obtain the substance as a glass were unfruitful.
$BaSiO_4$	1750°	—	,,	—	—
$ZnSiO_3$	1437±1°	3·52	,,	$n_1=1{\cdot}623$; $n_2=1{\cdot}616$.	Weakly double refracting crystals.
Zn_2SiO_4	1509°	—	,,	$n_1=1{\cdot}719$; $n_2=1{\cdot}697$.	Crystals identical with *Willemite.*
$CdSiO_3$	1242°	4·928	,,	Both >1·739.	Crystals with strong double refraction.
Cd_2SiO_4	1252–1243°	—	,,	Both >1·739.	,,
$MnSiO_3$	1273±1°	3·716	,,	$n_1=1{\cdot}739$; $n_2=1{\cdot}733$.	Artificial *rhodonite.*
Mn_2SiO_4	1290–1300°	4·044	,,	Both >1·739.	Artificial Mn_2SiO_4 has no fixed melting point. Became dark coloured on heating through decomposition.
$CaMg(SiO_3)_2$.	1391°	3·275	Allen & White.	$n_1=1{\cdot}664$; $n_2=1{\cdot}671$; $n_3=1{\cdot}694$.	—

free platinum dish in an electric oven, and then completing the fusion in a Fletcher gas furnace.

The silicates of barium, strontium, beryllium, zinc, and cadmium were white and crystalline; that of zinc showed a blue to violet colouring, whilst those of manganese developed a brown colour. In the table on p. 235 are stated some of the properties of the silicates.

n_1 and n_2 are the refractive indices for uniaxial crystals, and n_1, n_2, and n_3 for biaxial.

It was found that the meta-silicates have melting points which are related linearly to the atomic weights of the metals, the melting points rising with increasing atomic weights in the case of calcium, strontium, and thorium, and falling with magnesium, zinc, and cadmium. W. E. S. T.

308. Some Aspects of the Physical Chemistry of Fusing Silicates.

A. V. Bleininger (*Trans. Amer. Cer. Soc.*, 1907, 9, 419).—Measurements of volume showed that in nearly all cases, in fusing a crystalline silicate, the real volume seemed to increase, the effect of bubbles and cavities being eliminated. Quartz shows a decided increase, and felspar expanded to the extent of 6 per cent. By determining the change in volume with rise in temperature, it was found that felspar began its fluxing effect at a temperature much below its melting point, and the vitrification of a porcelain body began at quite a low temperature, while the effect of a flux such as lime was well marked. In a clay body, increases and decreases in volume might occur, and the resulting change in volume was the algebraic sum of many complex changes.

Ceramic silicates were on the borderline between glassy and crystalline structure. In an amorphous substance such as glass, the physical properties were the same in all directions, whereas in crystals they were alike, but in parallel directions. The author found that a specimen of paving brick, which gave poor results under the "rattler" test, showed signs of crystallisation, while the sound brick gave no such evidence.

On fusion, clay and crystalline bodies, such as quartz and felspar, reach a state of fluidity suitable for the production of crystals, which had been found in a piece of Chinese porcelain, and in a piece of a Berlin crucible.

Viscosity was a property of great importance in problems such as the crawling of glazes, and if too great, crystallisation was prevented. Many silicates had a high viscosity at the temperatures usually used. Very siliceous and aluminous silicates were completely viscous, whilst those of the alkaline earths became fluid more readily. For glasses to be blown or moulded, and for crystalline glazes, the change of viscosity with temperature must be of a certain order, and the condition of plasticity of kaolin and ball clay slips would no doubt be better understood from a determination of the viscosities.

Melting points and solidifying points were not necessarily identical for silicates, due to supercooling and supersaturation. In solid solutions, such as glass, fusion took place during an interval, and even quartz had a melting *interval* rather than a melting *point*, and mixtures of quartz and tridymite were obtained.

Melting and freezing curves were very important in studying the fusion phenomena of silicates, and supersaturation played an important part in crystallisation. A mixture of silicates fused at a lower temperature than the silicates themselves, and eutectic mixtures, that is, mixtures in a definite proportion, which fused at a lower temperature than either constituent, or any other combination of the two, could be calculated, or determined practically, as shown fully by the author. Kaolin added to a cone mixture rendered it more fusible, and fluxes were used in the production of glass or glazes for this purpose.

Le Chatelier observed an absorption of heat during the dehydration of kaolin between 550° and 650°, and also a sudden evolution of heat on heating kaolin to 1000°, corresponding with the isomeric change of state after which the alumina became insoluble in acids.

It was suspected that certain reagents brought about catalytic reactions in igneous mixtures; for instance, steam and hydrofluoric acid converted amorphous alumina into a crystalline variety.

The author discussed the rate of cooling of various types of silicates fully, and he showed the importance of, but the great lack of trustworthy data on, other physical properties, such as porosity, hardness, solubility, fineness of grain, elasticity, and coefficient of expansion. V. D.

309. Some Properties of Commercial Silicate of Soda. James G. Vail (*J. Ind. Eng. Chem.*, 1919, **11**, 1029).—A definite compound of the formula $Na_2SiO_3,9H_2O$ could be prepared, but, as far as was known, it had no commercial value, because it lacked those colloidal properties upon which practically all of the commercial applications of silicate of soda depended.

Sodium silicate in commercial use contained more silica than was indicated by the above formula, the ratio between Na_2O and SiO_2 varying between 1:4 and 2:3. Forms more alkaline than the 2:3 variety tended to form crystalline masses, which would interfere with their usefulness, and the practical limit in the other direction, 1:4, was determined by the very low solubility of fused sodium silicate containing larger proportions of SiO_2. Commercial grades of sodium silicate had the physical appearance of glass, but were less permanent and effloresced in damp air. They were usually coloured, owing to small quantities of iron present. Ferric iron, giving a yellow colour, was more frequently observed in the alkaline types, while those rich in silica were usually coloured green, due to the presence of ferrous iron.

The paper contained data relating to properties such as solution, colloidal nature, viscosities of solutions, strength of adhesives, and cements produced from sodium silicate, the author stating that further studies were in progress. C. M. M.

310. High Temperature Work on the Silicates. R. C. WALLACE (*Trans. Eng. Cer. Soc.*, 1909—1910, **9**, 172).—The main object of the work was to investigate several two-component systems of the metasilicates of the alkalis and alkaline earths, and the three-component system Na_2O,Al_2O_3,SiO_2.

The author found that the chief difficulty to be contended with was the tendency of the "melt" to solidify as a glass. A marked exception to this tendency, however, was lithium metasilicate, Li_2SiO_3, which was characterised by its extremely high rate of crystallisation. Hence it had been used in a large number of the two-component systems described. In most cases the mixtures were made from the carbonates and precipitated silica, the purest materials being employed. The following table summarises the chief results for the two-component systems examined:—

		Composition of eutectic.		Temperature of eutectic crystallisation.
Silicate pair.	Miscibility in crystalline state.	Percentage by weight.	Molecular percentage	
$Na_2SiO_3,CaSiO_3$ ...	Break in miscibility at 70–80% $CaSiO_3$... Minimum in curve at 20% $CaSiO_3$. Maximum in curve at 58% $CaSiO_3$.	70 $CaSiO_3$	71·1 $CaSiO_3$	1140°
$Na_2SiO_3,SrSiO_3$ ...	Completely miscible. Minimum in curve at 25% $SrSiO_3$.	—	—	—
$Na_2SiO_3,BaSiO_3$...	Completely miscible. Minimum in curve at 40% $BaSiO_3$.	—	—	—
$Na_2SiO_3,LiSiO_3$ ...	Completely miscible. Minimum in curve at 45% Li_2SiO	—	—	—
$Na_2SiO_3,MgSiO_3$...	Mixed crystals 0–10% and 90–100% $MgSiO_3$. From 20 to 80% $MgSiO_3$ the mixture was a glass.	—	—	—
$K_2SiO_3,Li_{22}SiO_3$ ...	Mixed crystals from 60–100% Li_2SiO_3. From 0–50% Li_2SiO_3 mixture formed a glass.	—	—	—
$Li_2SiO_3,CaSiO_3$ ...	Break in miscibility between 25–84% $CaSiO_3$.	50 $CaSiO_3$	43·7 $CaSiO_3$	979°
$Li_2SiO_3,MgSiO_3$ ...	Break in miscibility between 50–75% $MgSiO_3$.	55 $MgSiO_3$	52·3 $MgSiO_3$	876°
$Li_2SiO_3,BaSiO_3$ ...	Break in miscibility between 35–92% $BaSiO_3$.	78 $BaSiO_3$	60·2 $BaSiO_3$	880°
$Li_2SiO_3,SrSiO_3$ ...	Break in miscibility between 22–92% $SrSiO_3$.	6 $SrSiO_3$	45·3 $SrSiO_3$	1000°

Pronounced eutectic effects were noticed in the last four systems in the table, but a eutectic structure was not so definite. Such structures, the author stated, were not so well developed in the case of silicates as with alloys.

The molecular volumes of the mixed crystals in the $Li_2SiO_3,CaSiO_3$ and $Li_2SiO_3,BaSiO_3$ systems did not stand in linear relation to the concentrations. Only in mixtures of two saturated mixed crystals does such a relation hold.

Further work was done on the three-component system

$$Na_2O,Al_2O_3,SiO_2.$$

The paper was illustrated by numerous diagrams, graphs, and tables. C. M. M.

311. The Ternary System CaO-MgO-SiO_2. J. B. Ferguson and H. E. Merwin (*Amer. J. Sci.*, 1919, **48**, 81).—Of the four possible ternary systems which might be constructed from the four oxides, lime, magnesia, alumina, and silica, the system CaO–MgO–SiO_2 proved to be the most complicated. The salts used in the experiments were chemically pure calcium carbonate, magnesium carbonate, and silica, the magnesium carbonate being thoroughly calcined before use. Mixtures of known composition were melted in platinum crucibles and reduced to a fine powder. This procedure was repeated until the final products, glasses whenever possible, were homogeneous. When prepared, a small quantity of each product was heated to a given temperature, kept at that temperature until equilibrium was reached, and then quenched in mercury.

The following definite compounds appeared as primary phases:—

CaO,MgO (*periclase*), SiO_2 (*tridymite*), SiO_2 (*cristobalite*), melting point 1710±10°, α-$CaO.SiO_2$ (*pseudo-wollastonite*), $3CaO,SiO_2$, α- and β-$2CaO.SiO_2$, MgO,SiO_2 (*clino-enstatite*), $2MgO,SiO_2$ (*forsterite*), $CaO,MgO,2SiO_2$ (*diopside*), $5CaO.2MgO.6SiO_2$ (decomposition point 1365±5°), and $2CaO,MgO,2SiO_2$ (melting point 1458±5°).

Crystals also appeared as primary phases representing the following solid solutions:—a complete series with *clino-enstatite* and *diopside* as end-members, the *pseudo-wollastonite* solid solutions, the $5CaO,2MgO,6SiO_2$ solid solutions, and certain members of the *monticellite* solid solutions. The *monticellite* (CaO,MgO,SiO_2) solid solutions were dealt with in detail. Attempts to prepare pure *monticellite* did not succeed, a mixture of crystals of α-$2CaO,SiO_2$ and crystals of a *monticellite* solid solution always being obtained.

Fourteen quintuple points were found in this ternary system, the details being given as follows:—

	Composition.				Temperature.
	CaO.	MgO.	SiO_2.		
Eutectic	30·6	8·0	61·4	between *diopside*, *tridymite* and $5CaO,2MgO,6SiO_2$.	1320±5°
,, ...	36·0	12·6	51·4	between α-$5CaO,2MgO,6SiO_2$ solid solutions, *diopside* and $2CaO,MgO,SiO_2$.	1350±5°

	Composition.				
	CaO.	MgO.	SiO_2.		Temperature.
Eutectic ……	29·8	20·2	50·0	between $2CaO,MgO,2SiO_2$, *forsterite* and *diopside*.	1357±5°
,, ……	49·2	6·3	44·5	between *pseudo-wollastonite*, $3CaO,SiO_2$ and $2CaO,MgO,2SiO_2$.	1377±5°
,, ……	39·0	18·3	42·7	between $2CaO,MgO,2SiO_2$, α-$2CaO,SiO_2$ and a *monticellite* solid solution.	1436±5°
,, ……	uncertain.			between *periclase*, lime and α-$2CaO,SiO_2$.	Probably above 1900°
Non-eutectic …	31·3	7·2	61·5	between *pseudo-wollastonite*, a *wollastonite* solid solution and *tridymite*.	1335±5°
,, …	—	—	—	between *tridymite*, a *wollastonite* solid solution and a $5CaO,2MgO,6SiO_2$ solid solution.	Probably 1330±5°
	36·7	12·3	51·0	between *pseudo-wollastonite*, $5CaO,2MgO,6SiO_2$ and $2CaO,MgO,2SiO_2$.	1365±5°
	31·4	7·6	61·0	between *pseudo-wollastonite*, a *wollastonite* solid solution and a $5CaO,2MgO,6SiO_2$ solid solution.	1340±5°
	49·5	6·2	44·3	between β-$2CaO,SiO_2$, $3CaO,2SiO_2$ and $2CaO,MgO,2SiO_2$.	1387±5°
	33·3	22·3	44·4	between $2CaO,MgO,2SiO_2$, *forsterite* and a *monticellite* solid solution.	1436±5°
	37·3	22·3	40·3	between *periclase*, a *monticellite* solid solution and α-$2CaO,SiO_2$.	1498±5°
	32·1	26·4	41·5	between *periclase*, *forsterite* and a *monticellite* solid solution.	1502±5°

Full tables of details of experiments, concentration diagrams, models, etc., were also given. F. W. H.

312. Wollastonite (CaO,SiO_2) and Related Solid Solutions in the Ternary System Lime–Magnesia–Silica. J. B. Ferguson and H. E. Merwin (*Amer. J. Sci.*, 1919, **48**, 165).—The authors gave an account of a detailed investigation of the *wollastonite*, the $5CaO,2MgO,6SiO_2$, and other solid solutions briefly mentioned in a previous paper (*Amer. J. Sci.*, 1919, **48**, 81; preceding abstract).

The results which were obtained confirmed previous determinations regarding the *wollastonite–diopside* solutions. It was found that *wollastonite* took up a maximum of 17 per cent. of *diopside* to form solid solutions. The existence of a *pseudo-wollastonite–diopside* solid solution previously determined, and containing a maximum of 16 per cent. of *diopside*, was confirmed.

A new compound, $5CaO,2MgO,6SiO_2$, was found, and was described in detail. It decomposed at 1365°, about 25° higher than the decomposition temperature of the 17 per cent. *diopside* solid solutions. Other solid solutions discussed included those of *åkermanite* in *wollastonite* and also in *pseudo-wollastonite*, and the solid solutions of silica and $3CaO,2SiO_2$ in calcium metasilicate. The *wollastonite* solutions were shown to exist up to a composition having between 60 and 70 per cent. of *åkermanite*, whilst the *pseudo-wollastonite* solutions extended to a composition with about 23 per cent. of *åkermanite*.

There was also presented a general discussion of the results with illustrative diagrams and models. F. W. H.

313. Notes on the Development of the Ruby Colour in Glass. A. E. Williams (*Trans. Amer. Cer. Soc.*, 1914, **16**, 284).—Ruby glass is the term applied to glass coloured red by the use of gold, copper, selenium, and in some cases flowers of sulphur.

The author briefly reviewed the literature on the subject of the production of ruby glass by the use of gold, copper, selenium, and, in some cases, sulphur. The accepted view was that copper and gold were in the same condition as in colloidal solutions. According to Pöschl, particles of gold separated out from the glass on sudden cooling, but, having the magnitude of amicrons only, the glass appeared colourless. On re-heating to the softening point of the glass, the particles increased until they attained the size of ultramicrons, to which the colour was due. The same process occurred in the manufacture of copper ruby.

Several batches for the production of copper-ruby glass were quoted, chiefly from German literature, and mention was also made of gold, selenium and sulphur–red glasses. According to Hohlbaum, phosphoric acid and barium worked favourably in the manufacture of gold ruby, causing the colour to develop more quickly.

In new investigations on the development of the ruby colour, the author heated samples of a commercial copper-ruby glass (which had been cooled rapidly, and was therefore colourless) to definite temperatures in an electric oven, the rate of heating being carefully controlled. His results indicated that the colour produced at any particular temperature was constant and the colour change practically instantaneous, allowing for the time required for the temperature of the glass to become uniform throughout. In the case of the particular glass in question, no colour was developed below 600°; it was fully developed at 650°, and little or no change observed between 650° and 670°.

The method adopted by the author in his investigations was as follows: The glasses were fused in Battersea crucibles in a small gas-fired pot furnace, the temperature range required for firing and rendering the glass fluid enough to pour being between 1480° and 1520°. Half an hour was taken for complete fusion of the lead glasses and an hour for the leadless glasses. The melt was poured on to a thick iron plate and rolled out to a thickness of from 2 to 5 mm. The thinner portions were usually clear, and colour developed slowly in the thicker portions.

Three series of experiments were carried out.

Series A.—The glasses conformed to the general molecular formula $0{\cdot}5Na_2O : 0{\cdot}5PbO : 3SiO_2$, the batch weights being: flint, 90; red lead, 57; soda ash, 35·3; with 0·5 per cent. of cream of tartar added in each case to ensure reduction. The amounts of cuprous oxide and of oxide of tin were varied in successive melts, the limits being 0·018 to 1·4 parts of cuprous oxide and 0·3 to 3·0 parts of tin oxide to the above batch. Some good glasses were obtained in this series, but the colour change was too rapid to allow of adequate control of the uniformity of the colour. A portion of the lead was replaced by lime in order to harden the glass somewhat, but the results showed that this increased the rate of development of colour.

Series B.—The glass used as the basis for this series of experiments was made from the following batch: flint, 100; potash, 26; white lead, 30; borax, 10; soda ash, 13·2; cuprous oxide, 3·5; tin oxide, 2. One per cent. of cream of tartar was added in each case. In some cases small amounts of iron and manganese oxides were added, but the results were unsatisfactory. This series produced a much better red colour than was obtained in Series A, but generally the colour was too dense and difficult to control. More uniform results were obtained by pouring the glass into water and re-melting. The glasses showed a light amber colour at 500°, changing to light red at 525°, ruby at 550°, and becoming opaque at 600°.

Series C.—Leadless glasses with high silica content. The type of glass used in this series corresponded with the molecular formula $0{\cdot}536K_2O : 0{\cdot}440CaO : 4{\cdot}57SiO_2$, corresponding with a batch mixture of flint, 200; potash, 68; limespar, 32; with copper oxide, 1·2; tin oxide, 4·46; and cream of tartar, 2. This was found to be too hard, and the silica (flint) was reduced to 175 parts with the above batch. The resulting glass gave a good ruby colour on re-heating, but the temperature required to develop it properly was too high (850°). On replacing some of the lime by lead so as to soften the glass somewhat, much better results were obtained. Thus a clear deep ruby was developed at 570° on reheating a glass made from the following batch: flint, 175; potash, 68; limespar, 25; white lead, 15; cuprous oxide, 1·2; tin oxide, 4·46; cream of tartar, 2. The conclusions drawn by the author were as follows:—

(1) A workable ruby glass is one which will not become coloured

when cooled at the rate obtainable in the pressing process, and yet will give a workable range of temperature for reheating to uniform colour at temperatures below 700°.

(2) Highly fluid glasses become coloured more rapidly than viscous ones.

(3) Replacing lime with lead or soda increased the rate of colour development, lead more than soda.

(4) High silica is necessary for the development of good colour and to give sufficient viscosity, but increases the tendency to streakiness, particularly in lime–potash glasses. Small amounts of lead reduce streakiness.

(5) Iron and manganese are detrimental to good colour.

(6) Remelting improves the uniformity of the colour.

(7) The density of colour is apparently increased with increasing temperature. The time of heating is not an important factor.

J. H. D.

314. Contributions towards a Bibliography of the Art of Glass. M. L. Solon (*Trans. Eng. Cer. Soc.*, 1912-13, **12,** 65).—A bibliography of works on glass published in all European countries, divided into two parts, the first containing those relating to glass-making and technology, and the second to the history of the art, stained-glass windows, and description and illustrations of glass vessels, ancient and modern.

C. M. M.

III.—Lamp-worked and General Scientific Apparatus.

315. Glass Cutter. M. J. Scullin (U.S.A. Pat., July 1st, 1919, No. **1308260**. Filed January 23rd, 1918, No. 213330).—The glass cutter has a casing, 10 (Fig. 150), in the form of a tube of suitable length, with a measuring scale marked on the exterior. One end of the tube carries two curved bars, 13 and 14, serving as a handle, and the other end of the casing is slotted lengthwise, 15. A small cutting steel wheel, 16, is rotatably mounted on a rod, 19, held in the wall of the casing and allowing the wheel to rotate in a direction crosswise to the casing. A retainer element, 20, is provided to allow of the cutter being held in movable engagement with the glass, and to permit of its being used for cutting tubes of various diameters. This retaining element consists of an L-shaped lever, pivoted at 23 to the casing, so that the arm, 21, is on the inside of the casing, and is connected to the operating rod, 27.

A slideable stop, 29, is mounted on the casing and secured in any desired position by the set-screw, 32, so that any number of lengths of glass all of exactly the same length can be cut off.

S. E.

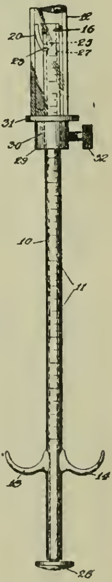


Fig. 150.

316. Machine for Shaping Tubular Glass Articles. R. Koenig (U.S.A. Pat., May 27th, 1919, No. **1304691.** Filed May 31st, 1918, No. 237425).—Lengths of glass tube are filled into a magazine, 15, mounted with its outlet above two pairs of rollers, 29, which are constantly rotated in the same direction by the belt, 30. Burners are fitted so as to heat each end of the tube as it is rotated, and when the glass is hot the forked prongs, 37, 38, and 39, are released by the two cams, 43 and 45, and pulled together by the coiled spring, 42. On coming together these three forks grasp the tube and lift it out of engagement with the rollers and up to such a position that its axis is in line with the axis of the shaping tool, 51. This shaping tool is rotated, and is slideably mounted within the bushing, 49. A coiled spring, 72, normally holds the sleeve, 50, in the outward position, but by the operation of the cams, 70 and 49, the latter pushes the tool towards the hot glass. When the centring head, 59, enters the end of the hot glass tube, further longitudinal movement is stopped, and the arm, 69, causes the sleeve, 50, to engage the tapered surfaces, 56, and thereby moves the jaws, 55, together. At the other end of the glass tube is a stop, 73, the horizontal position of which can be varied, and can be secured in any desired position by the nut, 74.

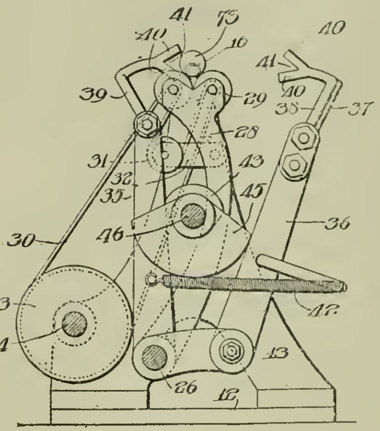


Fig. 151.

When the shaping of the neck is completed, the tool is withdrawn by the spiral spring, 72, and an ejecting arm, 79, pushes the finished tube from the rollers on to a chute, 80, leading to a collecting vessel. S. E.

317. Suggestions for the Standardisation of Chemical Glassware. H. Thiene (*Zeitsch. angew. Chem.*, 1920, **33,** 18).—The continuous endeavours which are being made to standardise the products of our industries have happily not stopped short of the apparatus used in the chemical laboratory. The Verein Deutscher Chemiker, in which there is a particular section concerned with chemical apparatus, has set up a series of commissions, each of which has its own sphere of investigation. I am directed by the commission on laboratory glassware, of which Prof. Böttcher, of Ilmenau, is chairman, to publish the proposals for the standardisation of the shape of laboratory glassware. Before stating the selection which has been made, let me bring to mind the very great diversity of existing shapes and sizes which are to be limited. Such a limitation is advantageous for all concerned, for producer, merchant, and consumer. When the purchaser has not several hundred shapes and sizes from which to choose, the majority of which are seldom asked for, the few standard types can be manufactured in greater quantities, and therefore more cheaply. The merchant needs to keep fewer shapes in his shop, and this again reduces the cost. Finally, the consumer has the additional advantage that the dealer will have these relatively few standard shapes already in stock, or they can be obtained immediately from the manufacturer.

After restricting the number of shapes, the question of the standard measurements of these standard shapes has to be considered. In this direction, the chemist is saved much time, expense, and vexation by standardisation. Hitherto, not only has each factory had its own particular measurements for height and width of neck, but it very often happened that articles were sold from the same factory and bearing the same distinguishing mark which differed so greatly that it was only with difficulty that a resemblance could be seen. Woe to the poor chemist who broke a flask in a larger piece of apparatus! A substitute of equal height, and even approximately the same width of neck, was to be found usually only with difficulty, particularly in the case of ordinary glass, blown either in a wooden mould or without one at all. Even though the articles sold by the Jena glass works had the same dimensions, reform was still needed with regard to the neck measurements, since, for example, Erlenmeyer and ordinary flasks of the same content had not the same neck diameter. I have therefore carried my suggestions further, and selected a number of sizes in every kind in order that they may have the same width of neck. In this way it is possible for the chemist to meet his requirements for ordinary and Erlenmeyer flasks with a very small number of stoppers.

I have entirely eliminated the short, welted round flask, the short flat, short round, and long flat Kjeldahl flask, the slender, conical beaker, as well as the evaporating dish with round bottom.

Before finally fixing the standard shapes and sizes, it is desirable to have expressions of opinion on my proposals from consumers, in particular as to whether or not a still further restriction of the types is possible. Is it necessary to produce high, squat (Griffin beakers) and conical beakers, or is not the Griffin beaker alone sufficient? Must flasks be made with welted and with turned-down edges, or is it not sufficient to have those up to 1 litre with welted necks and above that only those with turned-down edges? Are the long, round Kjeldahl flasks which I have proposed, and the squat, conical beaker the most suitable, even if the latter is still necessary, or are the longer, flat Kjeldahl flask and the slender, conical beaker to be preferred?

Griffin Beakers.

Capacity	50	100	150	250	400	600	800	1000	c.c.
Height	55	65	75	85	105	120	135	145	mm.
Width	45	50	55	65	75	85	95	105	mm.
Capacity	1¼	1½	2	2½	3	4	5	—	litres
Height	160	175	185	205	230	250	280	—	mm.
Width	110	120	130	140	145	150	160	—	mm.

Tall Beakers.

Capacity	50	100	150	200	300	400	500	600	800	c.c.
Height	65	80	90	100	120	130	140	150	165	mm.
Width	40	45	50	55	60	70	75	80	85	mm.
Capacity	1	1¼	1½	2	2½	3	4	5	—	litres
Height	185	205	210	235	250	280	290	320	—	mm.
Width	90	95	100	110	120	130	140	155	—	mm.

Squat, Conical Beakers.

Capacity	50	100	150	250	500	750	1000	c.c.
Smallest diam.	32	39	49	54	61	66	70	mm.
Greatest diam.	43	53	59	69	87	100	110	mm.
Total height	65	70	80	115	140	155	185	mm.

Erlenmeyer Flasks.

Capacity	25	50	100	150	200	300	500	750	c.c.
Outside neck width	20	20	20	25	25	25	30	30	mm.
Total height	70	80	100	120	125	145	185	205	mm.
Greatest diam.	35	45	60	65	75	80	90	100	mm.
Capacity			1	1½	2	3	4	5	litres
Outside neck width			30	40	40	40	50	50	mm.
Total height			220	250	275	320	340	390	mm.
Greatest diam.			105	115	130	145	155	175	mm.

Flat Bottom Flasks with Turn-down Edges.
Flat Bottom Flasks with Welted Necks.

Capacity	25	50	100	150	200	300	500	750	1000	c.c.
Outside neck width	20	20	20	25	25	25	30	30	30	mm.
Total height	70	80	100	120	125	145	185	205	220	mm.
Diam. of sphere	42	50	61	69	77	86	105	116	128	mm.
Capacity	1½	2	3	4	5	6	8	10	—	litres
Outside neck width	40	40	40	50	50	50	50	70	—	mm.
Total height	250	275	320	340	390	410	430	490	—	mm.
Diam. of sphere	148	168	190	205	220	240	260	280	—	mm.

Round Flasks, Long, Welted, or Turned-down Rims.

Capacity	25	50	100	150	200	300	500	750	1000	c.c.
Diam. of sphere	42	50	61	69	77	86	105	116	128	mm.
Total height	100	120	145	160	175	205	245	275	290	mm.
Diam. of neck	20	20	20	25	25	25	30	30	30	mm.
Capacity		1½	2	3	4	5	6	8	10	litres
Diam. of sphere		148	168	190	205	220	240	260	280	mm.
Total height		325	335	380	420	450	460	530	550	mm.
Diam. of neck		40	40	40	50	50	50	50	70	mm.

Wide-necked, Flat Bottom Flasks; Wide-necked, Round Flasks.

Capacity ...	50	100	150	250	500	750	1000 c.c.	1½	2	3	litres
Diam. of neck.........	30	30	30	45	45	45	65	65	65	65	mm.
Diam. of sphere ...	55	63	70	85	105	116	128	150	165	190	mm.
Total height	80	90	110	125	150	170	200	215	240	270	mm.

Distilling Flasks.

Capacity	508	100	150	200	300	500	750	1000	c.c.
Diam. of sphere	50	61	69	77	86	105	116	128	mm.
Total height	120	145	160	175	205	245	275	290	mm.
Diam. of neck	20	20	25	25	25	30	30	30	mm.
Diam. of tube	6	7	7	8	8	8	9	10	mm.
Length of tube	8	8	8	12	14	16	18	20	cm.

Kjeldahl Flasks, Round, Long.

Capacity	50	100	200	300	500	800	1000	1500	2000	c.c.
Total height	185	220	260	280	300	340	350	370	390	mm.
Diam. of sphere ...	50	56	71	80	95	115	125	145	150	mm.
Diam. of neck	20	20	25	25	30	30	30	40	40	mm.

Measuring Flasks.

Capacity	50	100	200	250	500	1000	2000	c.c.
Outside neck width...............	12	14	15	19	20	22	29	mm.
Total height	130	160	190	210	250	310	350	mm.
Greatest diam.	46	57	71	76	95	122	153	mm.

Measuring Cylinders.

Capacity	50	100	200	250	500	1000	c.c.
Diameter	27	36	...40	43	52	60	mm.
Total height	170	230	270	290	380	520	mm.

Flat Evaporating Dishes.

Capacity ...	5	10	30	90	150	300	500	1500	2500	5000	c.c.
Diameter ...	18	20	30	45	50	65	80	100	130	150	mm.
Outside measurement at the edge.	40	50	60	80	100	125	150	200	250	300	mm.

Crystallising Dishes.

Capacity ...	15	30	60	150	300	500	750	2000	3000	4500	c.c.
Outside diam.	40	50	60	80	100	125	150	200	250	300	mm.
Height.........	25	30	35	45	60	65	75	90	100	110	mm.

Watch Glasses.

Outside measurement	40	50	60	80	100	120	140	mm.
	160	180	200	220	240	—	—	mm.

Reagent Bottles.

Capacity	50	100	250	500	1000	2000	3000	5000	c.c.
Diam. of neck	17	18	22	23	30	35	40	45	mm.
Greatest diam.	43	53	67	83	108	140	155	175	mm.
Total height	80	100	135	160	190	230	270	310	mm.

Wide-mouth Bottles for Solid Reagents.

Content	50	100	250	500	1000	c.c.
Diam. of neck	27	36	38	48	60	mm.
Diameter	43	52	68	80	105	mm.
Total height	95	100	130	160	210	mm.

Retorts.

<table>
<tr><th>Content</th><th>50</th><th>100</th><th>250</th><th>500</th><th>750</th><th>1000</th><th>c.c.</th></tr>
<tr><td>Diam. of sphere</td><td>55</td><td>70</td><td>85</td><td>100</td><td>120</td><td>130</td><td>mm.</td></tr>
<tr><td>Length of still</td><td>180</td><td>190</td><td>250</td><td>275</td><td>330</td><td>350</td><td>mm.</td></tr>
<tr><td>Diam. of still at end</td><td colspan="2">12–14</td><td>15–17</td><td>15–18</td><td>17–20</td><td>20–25</td><td>mm.</td></tr>
<tr><td>Diam. of stopper</td><td colspan="3">15–18</td><td colspan="2">18–22</td><td>23–25</td><td>mm.</td></tr>
</table>

Receivers.

Content	50	100	250	500	750	1000	c.c.
Diam. of neck	22	24	30	34	36	40	mm.
Diam. of sphere	—	62	82	100	116	129	mm.
Total length	—	150	190	255	275	295	mm.

(Translation in full.)

J. R. C.

IV.—Decorated Glass.

318. The Preparation of Metallic Mirrors, Semi-transparent and Transparent Metallic Films and Prisms by Distillation. O. Stuhlmann, jr. (*J. Optical Soc. Amer.*, 1917, **1**, 78).—The essential part of the apparatus consisted of a wire heated to incandescence by means of an electric current, while the object to be covered with the metallic surface was placed below. If the air in the vessel containing the apparatus were evacuated, the metal vaporised and condensed upon the object. The wire was moved with uniform speed across the object, and a uniform coat of metal was thus deposited. The thickness of the film produced depended on the time of deposition, the temperature of the wire, the molecular weight of the vapour, and its vapour pressure. Any material could be coated provided it did not possess a pronounced vapour pressure at the ordinary temperature and a pressure of 0·002 mm. of mercury. To facilitate the deposition of opaque surfaces of silver, it was found practicable to use an alloy of 15 per cent. platinum and 85 per cent. silver. With this, the silver could be evaporated without melting the wire.

The method required that the surfaces shall be free from grease, but the elaborate cleaning necessary for chemical deposition is stated to be avoided. The deposit could be made on any material, even on paper, and its thickness was well under control. It did not need to be polished before use. A prism could be coated by allowing the wire to remain at rest. The method was superior to cathodic sputtering in that the particles did not penetrate into the glass, and so render the surface optically useless. J. R. C.

319. Protection of Silvered Surfaces. F. Kollmorgen (*J. Optical Soc. Amer.*, 1919, **2**—**3**, 16).—To protect silvered surfaces against atmospheric conditions, the author used a mixture of one part of Lastina lacquer and two parts of commercial thinning material. If only a thin layer of this were applied, the lacquer showed interference colours, and, at first, a thicker layer dried in waves and streaks. This difficulty was overcome by centrifuging the mirror during the drying. After a year's use in submarine periscopes the mirrors had shown no appreciable decrease in efficiency and no appearance of tarnishing. The lacquer was soft and easily scratched, and dust must be removed by a camel's-hair brush. Attempts to harden it by baking had not been successful.

J. R. C.

V.—Optics and Optical Instruments.

320. The Reflected Images in Spectacle Lenses. W. B. Rayton (*J. Optical Soc. Amer.*, 1917, **1**, 137).—Under certain conditions spectacle lenses caused stray patches of light and more or less distinct images to lie superimposed upon the field of view. The author analysed the effect of shape and power of the lens and derived formulæ for calculating the position of the images.

J. R. C.

321. The Astigmatism of Lenses. C. W. Woodworth (*J. Optical Soc. Amer.*, 1917, **1**, 108).—The author defined astigmatism as the asymmetry of the wave-front due to an eccentric stop, the eccentricity being in most cases relative to the object and dependent on its distance from the optical axis. This definition considers that astigmatism is not simply the condition opposed to homocentricity; a multicentric bundle is also not astigmatic if it is symmetric.

To clarify the situation, the author studied, with the aid of diagrams, the shapes assumed by the wave-front while passing through the focal region after refraction at a single spherical surface. In one case the section of the beam before refraction was circular and concentric with the optical axis, and in the other it was circular but eccentric with respect to this axis. The phases through which the wave-front passed in the focal region were examined. It was shown that every item of astigmatism could be worked out on the meridional plane, and for the purposes of lens calculation it was sufficient to compare the extreme ray on this plane with the chief ray to secure a true measure of the nature and the extent of astigmatism of a lens or optical system.

J. R. C.

322. The Design of Lenses for Aerial Photography. C. W. FREDERICK (*J. Optical Soc. Amer.*, 1919, **2—3**, 34).—An account of the development of such lenses in America during the war. Those used were of the four-piece, air-spaced type, of speeds from *f*4·5 to *f*6·0, and focal lengths from 10 to 20 inches. The author stated that the correction for spherical and chromatic aberration was not of very great importance, owing to the impossibility of focussing the camera properly. Coma also need only be reasonably well eliminated, though since it was easy to do this in a four-piece lens, the sine condition was satisfied within 0·3 mm. for all rays. It was important to avoid distortion, and the correction was reduced to less than 0·01 mm. at the extreme corner of the plate. The most difficult and most important of all corrections was held to be that for astigmatism. This was reduced to 0·5 per cent. of the focal length. All the lenses made were individually measured and adjusted upon the bench by changing the air spacing of the components. J. R. C.

323. Compound Lens Systems. T. T. SMITH (*J. Optical Soc. Amer.*, 1917, **1**, 113).—The author proposed a new solution of the problem of the formation of an image by two or more refractions. Two methods were described for the calculation of the constants in the equation, $u_{m+1} = (A_m u_m - B_m)/(C_m u_m - E_m)$, representing the case of m refractions. J. R. C.

324. Symbols and Designations for Geometrical Optics. H. KELLNER (*J. Optical Soc. Amer.*, 1917, **1**, 40).—An attempt to bring about a uniform system of designation. The author suggested that roman capital letters should be reserved for points, lower-case italics for magnitudes, italic capitals for reciprocals, and Greek lower-case letters for angles. Two exceptions were justified by universal usage, these being λ for the wave-length and Δ for the optical interval. The same letter or designation should be used for similar points or magnitudes on both sides of a refracting surface. Those on the emergent side of the surface were distinguished by a ′, for example, f and f' are the focal lengths.

For sign conventions, the original should be referred to. (Explanatory figures are given.) The designations proposed, it was stated, would be used throughout the *Journal* of the American Optical Society. J. R. C.

325. The Optical Properties of Light Filters. C. E. K. MEES (*J. Optical Soc. Amer.*, 1917, **1**, 22).—The optical effects produced by the use of colour filters might be divided, according to the author, into two classes. The first included those resulting from the use of a theoretically perfect filter, that is, a filter of which the faces were plane parallel and one which was free from strain. The effect of such a filter on the aberrations of a lens system and on the size of the image produced was discussed. It caused a species of spherical aberration all over the field, and the image was curved backward and slightly enlarged. The magnitude of the effects depended on the thickness of the filter and on the refractive index of the glass for different colours. The last factor would cause some chromatic aberration; this was shown, however, to be exceedingly small, and all the errors introduced were obscured by those of the second class arising from imperfections occurring in the filters. These were due to errors of surface and to the fact that the faces were not strictly plane parallel. The investigation of the effects produced could only be performed experimentally. The effect of a filter which showed strain and cylindrical curvature was illustrated by photographs. Good filters could not be tested by a coarse grid such as was used in this case, and a special test object was accordingly designed for observing the definition given by filters and for measuring their effect on the focal length of a lens. An instrument was also designed for measuring directly the difference in the size of the images produced by a set of three-colour filters, which differed slightly in thickness and also in focal length, due to cylindrical or spherical curvature of the faces. In a particular case where the image was 189 mm. long, a difference of thickness of 0·76 mm. produced an enlargement of 0·061 mm. When the difference in focal length of the filters was 37 mm. in 1500 mm., the difference in size of the images was 0·1 mm.

J. R. C.

326. A Compensating Filter in Spectroscopy. M. B. Hodgson and R. B. Wilsey (*J. Optical Soc. Amer.*, 1917, **1**, 86).—An extension of a method described by Luckiesh to obtain uniform photographic intensity throughout the spectrum, using a light source yielding a continuous spectrum. The spectrum was first photographed upon the particular brand of plates selected, exposing through the glass to avoid re-focussing in subsequent exposures. After development, this negative was used, with its emulsion in contact with that of the unexposed plate, as a compensating filter.

The use of such a filter was theoretically investigated by the authors, and they found that four conditions were necessary for success, namely: (1) The filter and the print plate must be made on plates of the same emulsion. (2) The filter must be neutral in colour. (3) All densities in the filter must lie on the straight-line portion of the characteristic curve. (4) The straight-line portion of this curve must have a slope of 1 for all wave-lengths. To secure a silver deposit of neutral absorption, elon developer was used, but it was stated that ferrous oxalate developer was even better. Examples are given of the preparation and use of the compensating filter described.

J. R. C.

327. Lippmann Colour Photographs as Sources of Monochromatic Light in Photometry and Optical Pyrometry. H. E. Ives (*J. Optical Soc. Amer.*, 1917, **1**, 49).—The Lippmann colour photograph consists essentially of a fairly transparent gelatin film in which lie thin layers of reflecting material. On illuminating such a film by white light, the reflected light is monochromatic, the wave-length varying with the angle of incidence. The mode of preparation of these films was described by the author. The paper also described two uses of the apparatus as sources of monochromatic light. The first use was as a substitute for coloured solutions or spectroscopic devices in the Crova method of eliminating colour difference in the photometry of two illuminants having continuous spectra. The theory of this method was stated, and the construction and calibration of a special eyepiece, containing the Lippmann film, for the Lummer-Brodhun photometer head described. The peculiar applicability of the film to the Crova method was illustrated by spectrographs, and a table of equivalent wave-lengths of several illuminants was given.

Another set of spectrographs illustrated the possible use of the film in optical pyrometry. The purity of the red light reflected from a film was greater than that transmitted by the best red glass, but the preparation of an optical pyrometer incorporating one of these films had not yet been undertaken. Trials with the optical parts of a Holborn-Kurlbaum instrument, however, showed that the construction could be carried out. J. R. C.

328. A New Type of Comparison Photometer. P. G. Nutting (*J. Optical Soc. Amer.*, 1917, **1**, 83).—A description of an instrument designed to replace the Martens photometer, but the use of calcite and of the polarisation principle were avoided in its construction. The light beam was divided and recombined by means of biprisms, and the density controlled in a known manner by means of a precision iris diaphragm or a neutral grey wedge inserted at the precise apex of the field pencils. The scale employed was empirical and very nearly linear. The chief advantage of this form of comparator was stated to be its freedom from errors due to polarisation in the light to be measured.

J. R. C.

329. Photo-electric Spectrometry by the Null Method. K. S. Gibson (*J. Optical Soc. Amer.*, 1919, **2—3**, 23).—A detailed description of apparatus suitable for the measurement of spectral transmissions.

Light from a source giving a continuous spectrum was analysed by a constant deviation spectroscope, the eyepiece of which was replaced by a second slit. The approximately monochromatic light issuing from this slit was received by a Kunz potassium hydride photoelectric cell, and the current through the cell was balanced by varying the distance of the source from the spectroscope against that from another cell which was rendered active by a constant illumination. The balance was obtained with and without the specimen (the transmission of which was to be examined) interposed between the source and the spectroscope. The ratio of the squares of the two distances at which balances were obtained determined the transmission of the specimen. The objections to which the photoelectric method of spectrometry is exposed were, according to the author, removed by this null method.

J. R. C.

330. A Photochemical Theory of Vision and Photographic Action. P. G. NUTTING (*J. Optical Soc. Amer.*, 1917, **1**, 31).—In this paper the known general laws of photochemical response to light were summarised and interpreted, and a general theory based on the law of molecular opacity outlined. J. R. C.

331. The Absorption of Ultra-violet and Infra-red Radiations by Glasses. A. W. SMITH and C. SHEARD (*J. Optical Soc. Amer.*, 1919, **2—3**, 26).—Twenty-nine glasses, designated variously as Euphos, Amethyst No. 1, Dark Amber, and so on, no compositions being given, were examined by the authors. A photograph, taken with a Féry quartz spectrograph, registered the transmissions in the ultra-violet. As the specimens were of different thicknesses, and the source of light (a condensed spark between electrodes of iron and an alloy of cadmium, aluminium, magnesium, and zinc) was unsteady, the results were not comparable. The "amethyst" glasses transmitted farthest into the ultra-violet, their limit being about $0{\cdot}319\,\mu$. Noviol *b* was the least transparent, absorbing all rays beyond $0{\cdot}5\,\mu$.

A Hilger infra-red spectrometer was used for the transmissions in the infra-red region. Transmission curves ranging from $\lambda = 0{\cdot}75\,\mu$ to $4{\cdot}75\,\mu$ were given for all the glasses except one, namely, "Pfund" glass, which absorbed the infra-red to such an extent that no transmission was measurable. A Nernst glower was used as the source of the radiations. All the curves were similar in that a large increase in the absorption took place at $\lambda = 3\,\mu$ until it was nearly total at $\lambda = 4\,\mu$. Near the visible region, many of the glasses showed selective absorption. J. R. C.

332. The Effects of Treating Glass Surfaces with Certain Lubricants. W. SHACKLETON (*Trans. Optical Soc.*, 1919, **20**, 155).—Tests were made with three lubricants, namely, Lasin, Everclear, and Nepheless, in order to determine which was the most effective in preventing "steaming" of the glass surface. The temperature at which the untreated glass was obscured was 19°, and this was reduced to $-6°$, $-8°$, and $-10°$, respectively, after the lubricant had been applied. Nepheless, a preparation made by the author, consisted of glycerine with 20 per cent. of sodium stearate added. J. R. C.

VI.—Illumination and Illuminating Ware.

333. The Fundamental Principles of Good Lighting. P. G. Nutting (*J. Frankland Inst.*, 1917, **184**, 287; from *J. Optical Soc. Amer.*, 1917, 1, 134).—This paper, based largely on experimental work on vision, was an attempt to outline the fundamental principles upon which the illuminating engineer might determine in any particular case the proper illumination to secure the desired quality of seeing at a minimum of expense. The first fundamental relation was that between sensation and light stimulus in the steady state. Four kinds of sensibility were defined by the author and measured. (1) Threshold sensibility, the reciprocal of the brightness just perceptible corresponding with each brightness of sensitising field viewed. (2) Photometric sensibility, the reciprocal of the relative difference in brightness of two adjacent fields when that difference is barely perceptible. (3) Flicker sensibility, measured by the just noticeable difference in brightness of two lights occupying the same field of view alternately. (4) Glare sensibility, measured in terms of a field just bright enough to appear glaring. A table of these sensibilities when the field brightness varied from 0·000001 to 10,000 millilamberts was given. It was found that the logarithm of the glare limit was a linear function of the logarithm of the field brightness, such that $G=1700B^{0\cdot32}$. Further, except at the highest intensities, the threshold sensibility $T=125B^{0\cdot66}$. Log B/T appeared to reach a maximum when B was about 1000 millilamberts, after which it rapidly decreased. The discrimination factor varied irregularly. Log $B/\delta B$ was approximately linear in the region from 10^{-4} millilamberts to 1 millilambert, and approximately constant thence up to 1 lambert, when it commenced to decrease.

The author divided the necessary requirements which must be provided for by proper illumination into three classes: (1) in which mere outlines of large objects were to be observed, as in riding along a country road at night; (2) where the outlines of small objects, as in reading, must be clear; (3) embracing sewing and arts and crafts, where critical judgment required was to be expressed by the eye. For class (1) little illumination was required, but glare should be carefully avoided, on account of the sensibility of the eye at this level. In class (2), the specification of a minimum discrimination factor, such as 0·5, was regarded as reasonable; brightnesses ranging from 1 to 250 millilamberts without glare within the field of view were to be chosen. For class (3), it was difficult to prevent eyestrain. The most suitable lighting was limited to nearly a single direction, and that quite elevated.

Ideal lighting was not necessarily that under which the eye was subjected to no glare or no strain whatever, but that which made possible the use of the eye under the most favourable all-round conditions.

J. R. C.

334. A Mathematical Study of a Headlight Beam. O. E. Conklin (*J. Optical Soc. Amer.*, 1917, 1, 155).—The author assumed that the headlight had a parabolic reflector and that the source of light was of finite dimensions. On these assumptions, the direction after reflection of the ray proceeding from any point of the source and striking any point on the paraboloid was determined. The formulæ derived for this direction were applied to a study of the effect of the shape of the light source on the shape of the beam. Two particular cases were considered, namely, when the filament used as light source was linear and when it was **V**-shaped. A satisfactory headlight should have a wide, horizontal spread in order to illuminate the roadsides, and a limited vertical spread in order to avoid glare. It was shown that the beam from the linear filament had the advantage in both respects. Another advantage lay in the simple structure of its beam, which should make it possible to design more efficient headlight lenses than those in use with the **V**-shaped filament. The author stated that only a small part of the difficulty encountered in producing a satisfactory headlight beam could be attributed to the inaccuracies of the reflector. J. R. C.

335. The Measurement of Reflection and Transmission Factors. M. Luckiesh (*J. Optical Soc. Amer.*, 1919, **2–3**, 39).—The author reviewed the conditions which influence the values of these factors determined by experiment. In the case of the reflection factor, the value obtained depended on the character of the reflecting surface, the location of the source of illumination, the solid angle subtended by the light source, the spectral character of the illuminant, and the method of photometry. He concluded that perfectly diffused illumination best met the requirements; that is, the light source should be of uniform brightness and should subtend an entire hemisphere. A simple apparatus which satisfied these requirements, and could be used with an ordinary photometer, was described.

In addition to the influences mentioned above, the transmission factor depended, in case one side of the specimen was rough, upon the direction in which the light passed through it. To illustrate this, a table was given of the transmission factors of glasses under various conditions. One side of the specimen was sand-blasted, etched, peddled, coarse-ribbed, fine-ribbed, or wavy-ribbed. The transmission factor was smaller when the smooth surface faced the light source, and the difference was greatest for a narrow beam of light, diminishing as the illumination became more diffuse.

J. R. C.

336. Lamp Manufacture. W. L. van Keuren. General Electric Co. (U.S.A. Pat., December 23rd, 1919, No. **1326121.** Filed June 11th, 1918, No. 239480).—In the machine covered by this patent, an electric lamp bulb is held with its open end vertically downwards in a rotatable holder. The stem is held inside the lamp and is rotated round the same axis and at the same speed as the bulb. The bore of the neck, 15, Fig. 152, of the bulb is considerably greater than the diameter of the flare, 16, of the stem. A fork, 17, is pivotally mounted on the head by means of an adjustable block, 19, in such a position that the free ends fit round the neck of the bulb, and exert a pull due to their weight, tending to elongate the neck of the bulb. As the glass is rotated in front of the burner, 12, a ring of glass is heated and softened, so that the fork pulling downwards causes it to decrease in diameter until the walls engage with the edge of the flare and become sealed to it. The flames continue to heat the glass until the waste portion below the flare has been drawn off.

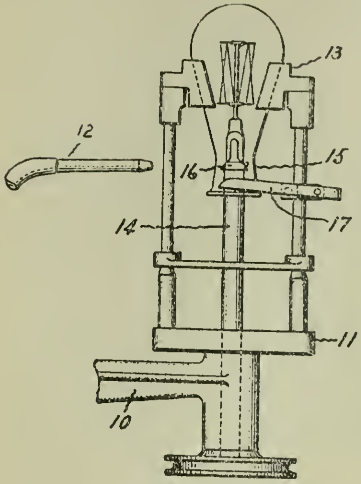


Fig. 152.

As the pulling down fork rotates with the bulb, it serves to hold it exactly concentric with the stem, and as there is no relative angular movement between the flared end and the fork, no twisting of the hot neck is caused.

In making tipless lamp, the flare has a notch in it, and this is kept open during the sealing-in operation by a pin fitted on to the conical surface of the holder, so that when the lamp is removed from the sealing-in machine there is an exhaust hole of the size of the pin through the flare. S. E.

VII.—Fuels, Refractories, and Furnaces.

337. An Improved Gas Producer. C. W. Lummis (U.S.A. Pat. No. **1305913**, June 3rd, 1919. Filed January 27th, 1915. No. 4650).—A gas producer constructed of an iron shell with a firebrick lining has a water-jacket surrounding the hottest zone of the producer, the firebrick lining at this point being comparatively thin. The object is to protect the brick from fusion and at the same time to prevent the adjacent portions of the feed bed being cooled to such a degree as to impair the gasifying operation in these parts of the fuel bed. In the construction shown in the drawings, the upper part, 2, of the producer, which is supported by standards, 2′, is separate from the lower or fuel-containing part, 5, so that the fuel section may be rotated if desired without interfering with the arrangement of the gas flues, 4. The lower section consists of a flared iron shell, 5, lined with firebrick, 7, the upper part, 8, of this lining, which is situated in the zone of greatest heat, being about one-half the thickness usually employed. It is stated that a thickness of 4½ inches has been found suitable with the ordinary grade of firebrick. Around this zone, the iron shell is formed as an open trough, 10, which forms a jacket for the constant circulation of cooling water, and also receives a depending portion, 12, of the shell of the upper section, 2, and thus forms a seal to prevent the escape of gas. It is stated that the water-jacket cools the lining below the point of fusion, yet the lining prevents excessive cooling of the neighbouring portions of the fuel bed. G. D.

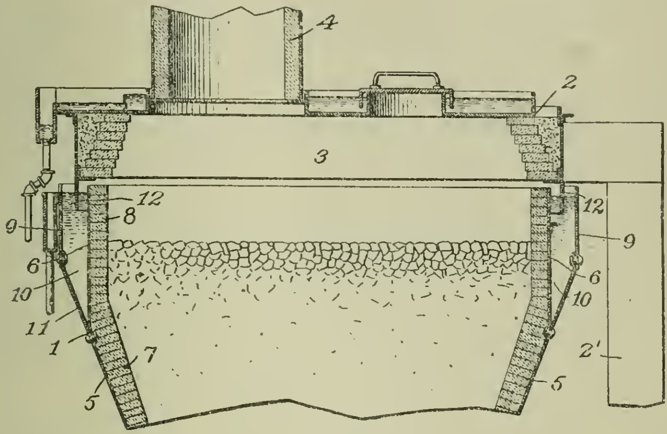


Fig. 153.

338. The Selection of Refractories for Industrial Furnaces. W. F. Rochow (*J. Ind. Eng. Chem.*, 1919, **11**, 1146).—The author pointed out that economy in the use of refractories was governed largely by the selection of the class of material best suited for the desired purpose, the quality of the brick, and the design of the furnace. He also emphasised the importance of good bricklaying, care in storing and handling, and proper manipulation and control of the furnace. The proper material to use would be determined by careful study of the properties and of the actual working conditions, together with practical trials. A superficial consideration of these factors, however, was not enough, for economies have resulted in some instances from the use of refractories the chemical composition and physical properties of which would indicate that they were entirely unsuited. Thus, in the glass industry, silica bricks were used almost exclusively in the roofs of tanks and pot furnaces, although subjected to the action of alkaline vapours. In this case, other refractories which might resist the chemical action better had not the same combination of other desirable properties which made silica superior.

In this paper the author dealt principally with silica and magnesia refractories.

Silica Refractories.—The main advantages were their high thermal conductivity, mechanical strength, and resistance to abrasion at furnace temperature, thermal expansion, spalling tendency, and high softening and fusion point. Together with its other properties, the good conductivity of silica rendered it the best suited material for the construction of the greater part of by-product coke ovens and other furnaces in which heat must be transferred through the refractory. Advantage of its conductivity was also taken in enamelling furnace muffles. In this instance, silica was not confined entirely to the muffle, but was also used in the combustion chamber, in which type of furnace the proper control of the temperatures on heating and cooling was important to avoid danger from spalling. With regard to thermal expansion, it was interesting to note that most of the expansion occurred over a narrow range and at comparatively low temperatures, the critical range being up to about 500°.

In spite of the high thermal conductivity, its good mechanical strength at high temperatures made it possible to insulate silica bricks under very difficult conditions. In contradistinction to fireclay and magnesia refractories, there was only a narrow temperature range between the softening and fusion points of silica, and hence no deformation occurred up to the melting point. Insulation with kieselguhr had been found to afford appreciable saving in silica bricks used in arches and subjected to high temperatures.

For a high-grade silica brick, Nesbitt and Bell secured an average crushing strength of 1831 lb. per sq. inch at 1350°. The same investigators found that the best clay brick had a crushing strength of 1289 lb. per sq. inch at 1350°. From the load test of the American Society for Testing Material, most fireclay bricks settled somewhat under a pressure of 25 lb. per sq. inch at 1350°, while good silica bricks remained rigid under the same load at 1500°. In selecting refractories, this test was of considerable value, but the conditions, when applied industrially, were seldom as severe as the load test, because only a small portion of the brick was exposed to the intense furnace heat, the remainder of the brick actually supporting the load being comparatively cold.

The specific gravity, in addition to chemical analysis and the load, fusion, and spalling tests used for determining the quality of silica bricks, might be used as a test of the extent to which the permanent expansion should be carried in the first firing. D. W. Ross suggested that a specific gravity of 2·38 might be taken as the upper limit for well-burned brick of the Medina quartzite of Pennsylvania.

Much information of practical value could often be gained by examining the remaining portion of the brick after long use.

Magnesia or Magnesite Refractories.—The author stated that the presence of iron in any proportion lowered the fusion point, but in quantities of from 4·5 to 8 per cent. of ferric oxide it widened the range of vitrification and developed good bonding properties at furnace temperatures. At high temperatures, magnesia bricks were not mechanically strong or resistant to abrasion. They expanded considerably, with the maximum expansion occurring at about 1350°, but on account of this high thermal expansion they had a tendency to spall when heated or cooled too rapidly.

In some cases, it has been found that the use of metal-encased magnesia brick in place of the ordinary magnesia and silica brick has proved an economy. At the temperature of the furnace the steel container melted back 1 or 2 inches from the exposed surface and impregnated the dead, burned magnesite which it enclosed. Thus the surface became practically jointless, which factor, together with the more open structure of this type of material, reduced the spalling tendency and made it considerably less than that of magnesia or silica brick. The stiffening effect of the unfused metal also helped to reduce spalling to a minimum. This brick had been found satisfactory in the back walls, bulk-heads, and gas ports of basic open-hearth furnaces, and in the side walls of electric steel-melting furnaces.

In addition to the physical and chemical properties of refractories, the design of the shape used was worthy of careful attention; difficult and intricate shapes should be avoided as much as possible.

C. M. M.

339. Superior Refractories. Ross C. Purdy (*J. Ind. Eng. Chem.*, 1919, **11**, 1151).—Only such materials as pure silicon carbide, fused alumina, sintered magnesia, fusel spinel, crystallised *sillimanite*, and calcined zirconia would meet the excessively high temperature requirements, and have at the same time the many other desired heat, strength, and dielectric properties. Which of the above-mentioned refractory materials would be most suitable in a given case would be much more dependent on physical than on chemical conditions, and the desired physical properties could be obtained with much greater certainty with such refractories than with such materials as clay, bauxite, or calcined magnesite, in which the physical-chemical reactions were only partially completed in the fabricated refractory product.

The author stated that there need be either no bonding material used or but a small per cent. of very fusible material, such as silicate of soda, very fusible clay, or stoneware glazes, in the cases of the superior refractories under discussion. C. M. M.

340. Relative Volatilities of Refractory Materials. W. R. Mott (*Trans. Amer. Electrochem. Soc.*, 1918, **34**, 255).—Using the electric arc, the author determined the volatilities of metals, carbides, nitrides, fluorides, chlorides, sulphides, and oxides. Ten different methods of measuring the volatilities were described, each method having its particular sphere of usefulness. The boiling points determined were compared, for standardisation purposes, with the boiling points of tungsten (taken as 6000°) and iron saturated with carbon (taken as 3500°), the temperature of the positive crater of the carbon arc being taken as 3700°. The distillation order of metals not uniting with carbon was found to be:—cadmium, zinc, thallium, lead and bismuth, antimony, silver, tin and copper, and gold. With the exception of manganese, the metals of the iron group did not separate well on distillation in the arc.

The distillation method was applied to mixtures of various metals with half a gram of iron, the metals used having higher boiling points than that of iron. Various amounts of the metals were used, and the following table gives some of the average total times for complete volatilisation of the test substances after the iron had been volatilised:—

Weight in mg. of element used.	Times (in minutes) required for various elements.						
	W.	Ta.	Mo.	Os.	Ir.	Pt.	V.
64·0	95·0	22·0	27·0	12·0	15·0	8·0	6·0
32·0	46·5	15·75	16·0	10·25	11·0	6·0	5·0
16·0	24·0	10·7	9·0	8·0	7·0	4·0	3·0
8·0	17·0	8·0	8·0	6·0	4·5	3·0	1·25
4·0	15·0	8·0	5·5	4·0	3·5	1·0	0·25
2·0	12·0	7·0	4·5	2·5	2·5	0·5	—
1·0	10·5	6·5	3·5	2·5	2·0	0·33	—
0·5	8·0	6·5	—	—	—	—	—
0·0625	4·0	5·7	—	—	—	—	—

From the consideration of all the results by various methods and the published results of other workers, the following series of boiling points was derived:—

Tungsten (carbide ?)	6000°	Platinum	4050°
Tantalum (carbide ?)	5500	Rhodium	4000
Zirconium (carbide)	5100	Vanadium carbide.........	3900
Thorium carbide	5000	Chromium carbide	3800
Yttrium carbide	4600	Aluminium oxide	3700—3800
Molybdenum carbide	4500	Carbon (sublimes)	3700
Osmium	4450	Magnesium oxide	3600
Iridium	4400	Silica	3500
Thorium oxide	4400	Calcium oxide	3400
Zirconium oxide	4300	Chromium oxide (Cr_2O_3)	3000
Yttrium oxide	4300	Titanium oxide—below.	3000
Titanium carbide	4300	Barium oxide	2000

The oxides and carbides of zirconium, thorium, titanium, rare earths, and alkaline earths had boiling points 1000° to 2000° higher than those of the elements themselves. Aluminium oxide boiled at 3700°, whilst aluminium boiled at 1800°. The volatility of the oxides took the following approximate order:—K_2O, Na_2O, Li_2O, V_2O_5, B_2O_3, BaO, SrO, MnO, FeO, CoO, NiO, Cr_2O_3, TiO_2,

V_2O_4, SiO_2, CaO, MgO, (xCaO,SiO_2), (xBaO,$y$$Al_2O_3$), Al_2O_3, TiO_3, V_2O_3, ZrO_2, ThO_2.

A summary of references was given relating to data bearing on the volatilities of materials. In an appendix the author gave a list of ratios obtained by dividing the boiling-point temperatures by the melting-point temperatures, both being calculated on the absolute scale. The ratios so obtained were very similar for elements of the same periodic group, and corresponding peculiarities were found in each group. The alkali group gave the highest average ratio, about 3·3. The general ratio was about 1·8, and, using this ratio, the author calculated a large number of boiling points. F. W. H.

341. Melting Points of Refractory Materials. C. W. Kanolt (*Trans. Amer. Cer. Soc.*, 1913, **15**, 167).—In the case of complex substances, such as fire-bricks, a true melting point is not obtained, since several anisotropic phases may exist all differing in composition from the isotropic phase produced by fusion. The lowest temperature at which a small piece of brick could be seen to flow was taken as the melting point. The author determined the melting points of many samples of fire-bricks, using an Arsem graphite resistance vacuum furnace and a Morse optical pyrometer. In order to distinguish the sample and watch it during heating, it was placed slightly below the hottest part of the furnace. The results obtained are given in table I.

Table I.

Material	No. of samples.	Temperature of visible flow.
Fireclay-brick	41	1555–1725° (mean 1649°)
Bauxite-brick	8	1565–1785°
Silica-brick	3	1700–1705°
Chromite-brick	1	2050°
Magnesia-brick	1	2165°
Kaolin	1	1735–1740°
Bauxite	1	1820°
Bauxite clay	1	1795°
Chromite	1	2180°

In the case of fire-bricks, lumps of foreign matter could be seen melting at a temperature different from that of the mass.

Determinations were also made on the pure refractory oxides, precautions being taken to use crucibles which would produce no contamination during heating, and to overcome the interference of the pyrometer readings caused by the evolution of dense vapour from the oxide.

The results of the work on MgO,Al_2O_3,Cr_2O_3 appear in table II. Many of the bricks tested above were also tested under load. Usually there was not much relation between failure under load and melting point. The relative importance of the tests depended on the conditions obtaining in the ultimate use of the brick.

TABLE II.

Material.	Individual determination.	Weight.	M. p. under load.
Cr_2O_3	1990°	3	1990°
	1991	1	
	1982	1	
	1979	2	
	2000	3	
Al_2O_3	2045°	3	2049°
	2053	1	
	2053	2	
	2041	2	
	2055	3	
	2046	2	
MgO	2808°	3	2800°
	2780	2	
	2818	3	
	2771	1	
	2799	2	
	2799	3	

V. D.

342. The Humidity System of Drying. E. D. GATES (*Trans. Amer. Cer. Soc.*, 1909, **11**, 375).—In order to eliminate the unequal shrinkage, and the resulting cracking and warping of terra-cotta ware, on drying, the author introduced live steam into the driers, while raising the temperature, and the humidity was kept so high that no moisture could be absorbed by the air from the ware. Thus no drying could take place until the humidity was allowed to fall, and this was avoided until the ware had assumed the temperature of the drier. Then the steam was shut off and air passed through the steam coils and drier to carry off the moisture from the ware. The steam used helped to heat the chamber.

The author described the arrangement of the coils in the driers, where the humidity was maintained at 80 per cent. until the ware was heated, then, after several hours, the amount of steam injected was gradually decreased and air allowed to enter, when drying began.

From many and varied experiments, the author concluded that:—

(1) A clay body can be heated more quickly and safely in a high humidity atmosphere than was possible with a low humidity, and the body could be raised to a higher temperature.

(2) Actual drying started sooner if the piece were preheated.

(3) Drying could be controlled by regulating the humidity, and took a much shorter time than ordinarily.

(4) Some types of bodies expanded and cracked if heated too rapidly. Heating was safer and quicker with a clay of larger water content than with a stiff sample, suggesting that the clay must be properly aged and worked in order to give successful drying by this method.

V. D.

343. Regenerating Chambers. F. J. Denk (*National Glass Budget*, 1919–20, **28**, 1, and 1919–20, **29**, 1).—Owing to the low heating value of producer gas (140 B.T.U. per c. ft.) as compared with that of natural gas (1000 B.T.U. per c. ft.), American manufacturers had to consider the question of checker chambers for their furnaces. It was not necessary, and not advisable, to preheat natural gas, even when used in direct-fired furnaces, and in many cases preheating of the air was unnecessary in order to obtain the required melting temperature. A decrease in the supply of natural gas forcibly introduced producer-gas practice, with the result that the existing furnaces required considerable modification.

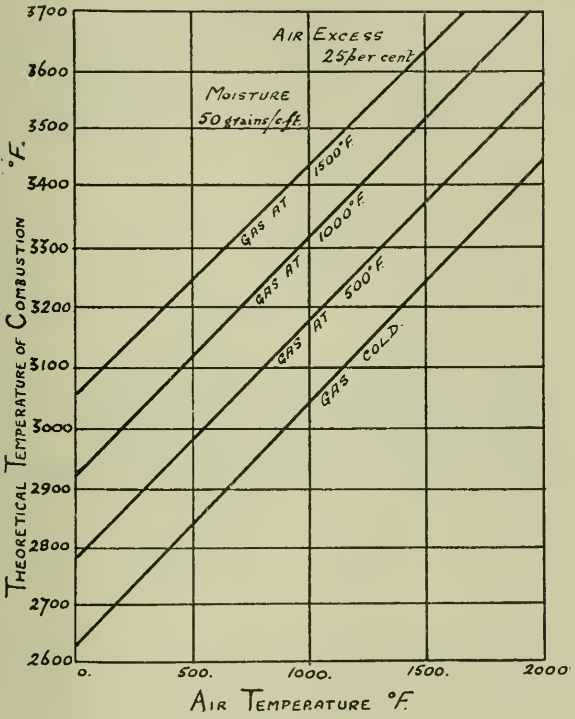


Fig. 154.

The author discussed the two essential requirements for regenerating chambers. They should be so constructed as to abstract as much heat as possible from the waste gases and transfer it to the incoming gas and air, and also to afford easy passage to both incoming and outgoing gases, a vital necessity for efficient furnace work.

In connection with the first requirement, a series of calculations was made, and the results plotted as curves, from which, by interpolation, all required data could be obtained to determine conditions affecting regeneration. The first series (Fig. 154) showed the theoretical temperature of combustion of a rich producer gas (30 per cent. CO and 4 per cent. CO_2) for different temperatures of the air and an air excess of 25 per cent. The second series (Fig. 155) showed the influence of the amount of excess air on the temperature of combustion of a good producer gas (30 per cent. CO and 4 per cent. CO_2), and also on that of a bad producer gas (20 per cent. CO and 8 per cent. CO_2), both gas and air being preheated to 1000°. In both series the moisture content of the producer gas was assumed to be 50 grains per c. ft.

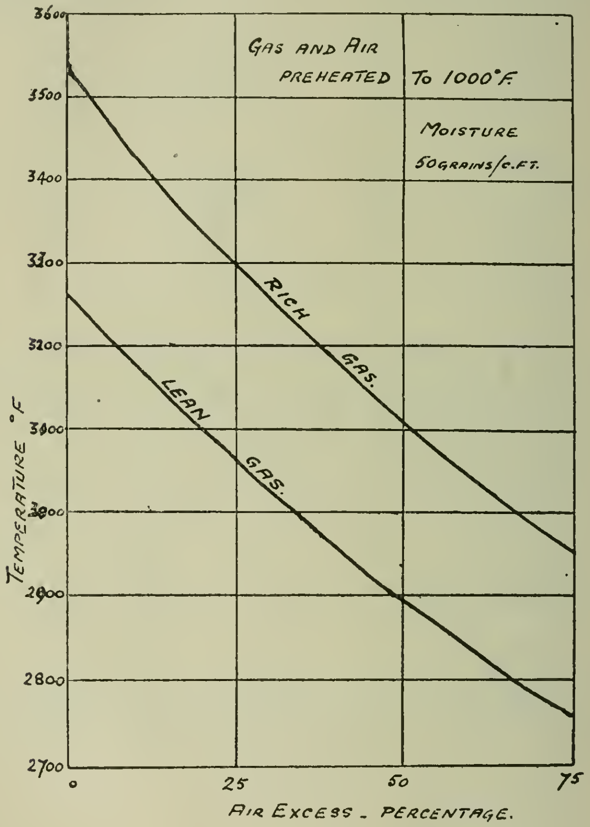


Fig. 155.

Although it was found that the actual flame temperature was about 500° F. lower than the theoretical temperature of combustion, it was considered that, other conditions being equal, the temperatures of combustion allowed a fairly accurate estimate of the actual flame temperature to be made. Whereas the theoretical temperature of combustion for cold gas containing 30 per cent. CO and 4 per cent. CO_2, with air preheated to 1000° F., was 3025° F., giving an actual temperature of 2500° F., the theoretical temperature of combustion of a gas with 25 per cent. CO, calculated under precisely similar conditions, was about 2875° F., corresponding to an actual temperature of about 2400° F. The latter temperature was too low for ordinary glass melting, and hence regeneration was necessary when using a producer gas with 25 per cent. CO or less.

Although harmless, it was not necessary to have a temperature in the regenerators of more than 1500° F., for with 25 per cent. excess of air and a gas with 25 per cent. CO, both gas and air being preheated to 1000° F., the theoretical temperature of combustion would be 3180° F., corresponding to an actual flame temperature of 2700° F. If the percentage of CO were below 25, a slight increase in the temperature of the regenerator would make up the deficiency in heating value.

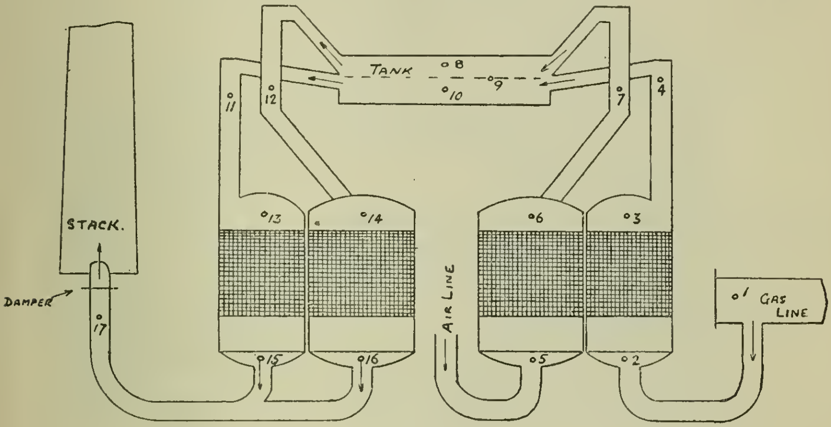


FIG. 156.

From Fig. 155, illustrating the influence of excess air on the temperature of combustion, it was shown that the temperature of combustion decreased with increasing excess of air, and that the highest flame temperatures were obtainable with the theoretical quantity of air. Producer gas could not be burned in present furnaces without excess of air, but the excess should not exceed 25 per cent. For the efficient working of regenerators it was further recommended that reversals should be made at regular intervals, the intervals not being too long; sizes of valves and chambers should be carefully calculated, and the walls of chambers and furnace watched carefully to avoid the presence of cracks and holes. When the most suitable steam pressure had been found for use with the particular coal available for the producers, it should be strictly adhered to, and there was no reason why the gas should not contain regularly 24 to 26 per cent. of CO. Regular determinations of CO and CO_2 should be made in order that the causes of production of poor gas might be immediately removed.

In order to obtain satisfactory heat absorption and transference in the regenerative chambers, it was possible that free passage of gas through the chambers might be seriously hindered, with a corresponding decrease in the furnace efficiency. The following table shows the general conditions which should, in the author's view, operate in regard to draught and pressure, whilst Fig. 156 illustrated the positions at which measurements were taken.

Point.	Location of Point.	Average pressure or draught ; inches W.G.
	Gas Line.	
1	Between reversing valve and regenerator.	+0·6
2	Below regenerator.	+0·2
3	Above ,,	+0·16
4	Between gas chamber and port.	+0·28
	Air Line.	
5	Below regenerator.	−0·04
6	Above ,,	+0
7	Between air chamber and port.	+0·12
	Furnace.	
8	Above centre line.	Very small pressure.
9	On centre line.	+0
10	Below centre line.	Very small draught.
	Flue gas line.	
11	Between port and gas chamber.	−0·12
12	,, ,, air ,,	+0·06
13	Above regenerator—gas.	−0·58
14	,, ,, —air.	−0·58
15	Below ,, —gas.	−0·76
16	,, ,, —air.	−0·72
17	Near stack damper.	−1·32

+ indicates pressure. – indicates draught.

The data given are intended to be read relatively, but draught and pressure, respectively, should be found in other furnaces at similar points to those indicated in Fig. 156. The reasons for the existence of draught and pressure at various points were given and discussed in detail, and indication was also given of how those conditions could be made of use in order to determine the causes of lack of efficiency in the furnace.

The causes of fusion in the regenerative chambers were enumerated, and it was emphasised that furnaces should be designed in such a way as to minimise all the possible defects, so as to prolong the life of the furnace. F. W. H.

344. The Simplex Muffle Lehr. C. E. FRAZIER (*National Glass Budget*, 1919–20, **2**, 1).—In the average open type of lehr the following disadvantages were found:—(1) glass could not be satisfactorily annealed, owing to the arch being further away from the glassware in the centre of the lehr than at the sides; (2) to obtain sufficient heat to anneal the glass properly in the centre of the lehr, it was often found that the glass at the sides was melted down; (3) glassware from an open-type lehr, whether the lehr was fired by producer gas or fuel oil, was always covered by a bloom.

The muffle lehr prevented the bloom being deposited on the glass, since the flame did not come into contact with the glass. The circular arch muffle type lehr prevented the bloom, but owing to severe loss caused by breaking of tiles, particularly in the centre of the arch, the Simplex muffle lehr was designed, with a flat arch supported by cast iron and permitting the use of thin tiles, and accordingly increasing radiation and decreasing fuel consumption. Tile breakage was reduced to a minimum, since the tiles had only their own weight to support, and the construction of the lehr was such as to allow free expansion and contraction. Broken or cracked tiles could be replaced through the "clean-out" doors whilst the lehr was in operation. The burner, of simple and strong

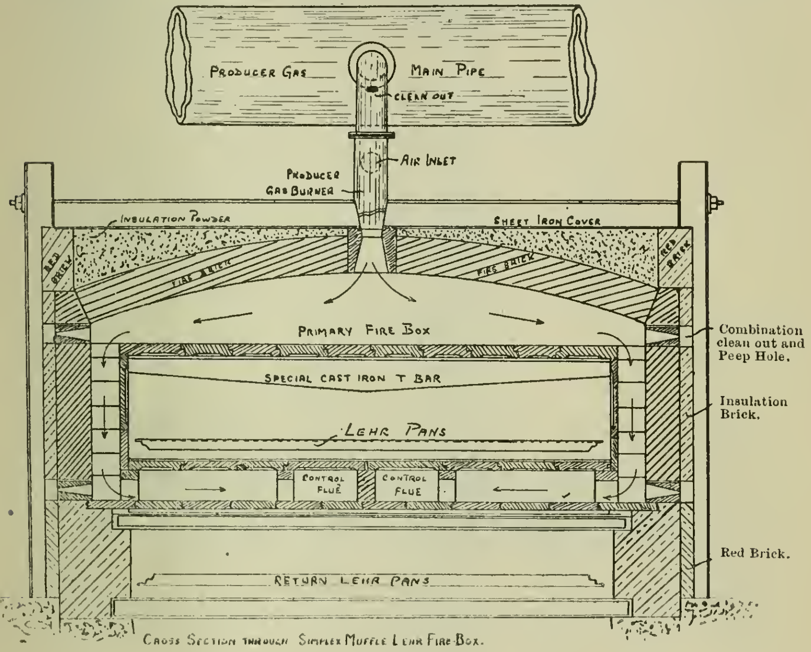
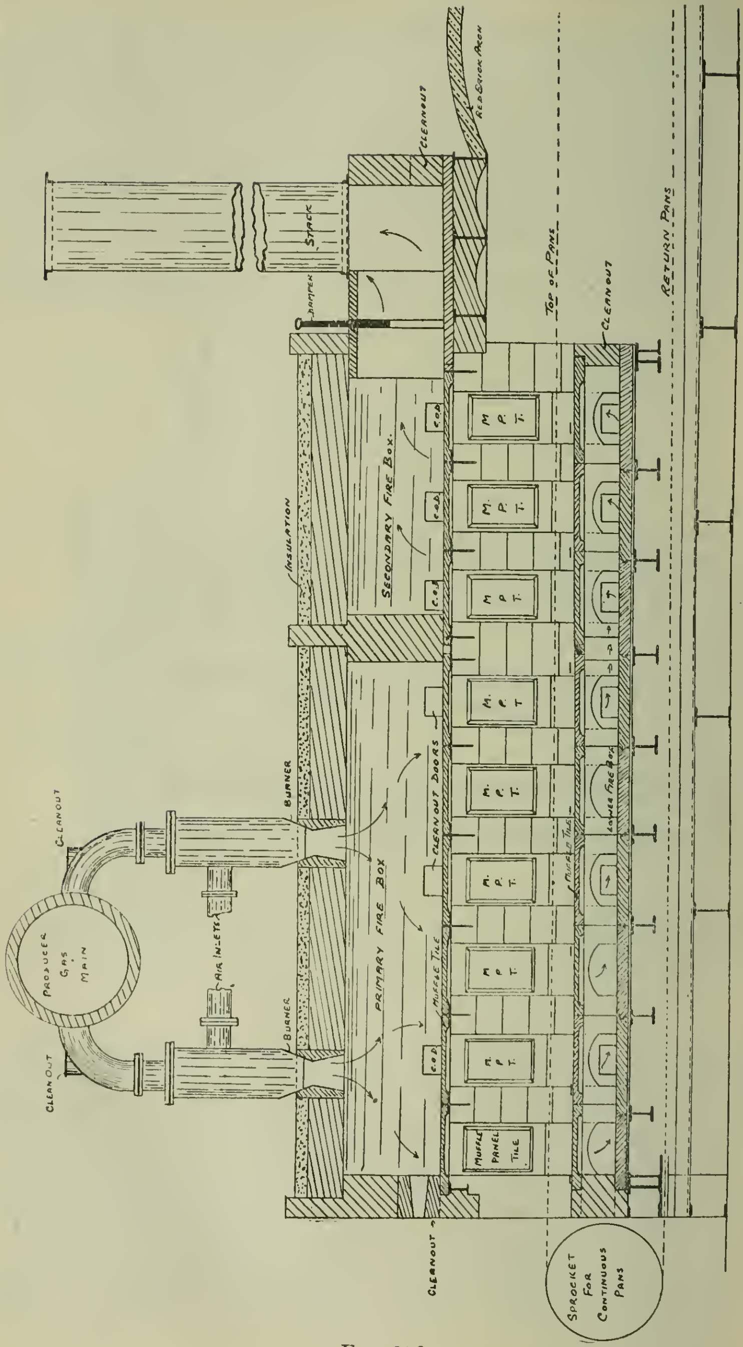


FIG. 157.



Longitudinal Section through Simplex Muffle Lehr Fire-Box.

Fig. 158.

construction, was in the top of the fire-box, the flame being drawn down either side and underneath the pans; it was also in an easily accessible position and ensured a self-cleaning fire.

Draught control being applied to each lehr, a uniform temperature was obtained throughout the fire-box, together with an economical distribution of heat. The system of dampers in the fire-box was so arranged as to permit of transference of heat to wherever it was necessary. Compared with the open-type lehr, the Simplex muffle lehr proved that a uniform temperature throughout the fire-box and a uniform fall of temperature throughout the first 25 feet were essential to the efficient annealing of glassware. The following figures show the difference in this respect between the open type and muffle type of lehr:—

Distance from front of lehr.	Temperature. Open lehr.	Temperature. Simplex muffle lehr.
9 feet	900°	900°
15 ,,	725	820
20 ,,	560	760
25 ,,	525	700
30 ,,	420	580
35 ,,	300	440
40 ,,	220	380

The Simplex muffle could be applied to old lehrs, whether of hand-pulled or continuous type, at a small cost. F. W. H.

345. Muffle Lehrs. B. F. Morton (U.S.A. Pat. No. **1295564**, February 25th, 1919, Filed September 13th, 1918, No. 253948).—In a muffle lehr the muffle is supported by two sets of arches within the combustion chamber, and is so constructed as to prevent leakage of gas from the combustion chamber into the muffle. Fig. 159 is a longitudinal section of the front end of the lehr, and Fig. 160 is a cross-section. Gas is admitted by a valve, 10, to a longitudinal duct, 6, which is separated by longitudinal walls, 7, Fig. 160, from two air ducts, 4. The tops of these ducts are formed by tiles, 11, which also form the floor of the combustion chamber, 12, apertures, 13, 14, in the tiles admitting air and gas respectively into the combustion chamber. The gas and air are preheated before mixing by heat from the bottom of the chamber, 12. Within the combustion chamber are a number of arches, 16, which support the bottom, 17, of a muffle, 18, the arches and the bottom, 17, thus forming the top chamber. The roof of the muffle is formed of T-shaped tiles, 21, Fig. 159, which in turn support tiles, 22, the legs of the T-shaped tiles, 21, being straddled by the flanges of channelled tiles, 23 The whole forms a composite arched roof for the muffle, the joints of which are gas-tight. The spaces, 29, between the channelled tiles, 23, form secondary combustion chambers communicating with the main combustion chamber, 12, and also, by means of ports, 32, in the crown, 20, with a longitudinal flue, 26, built above the

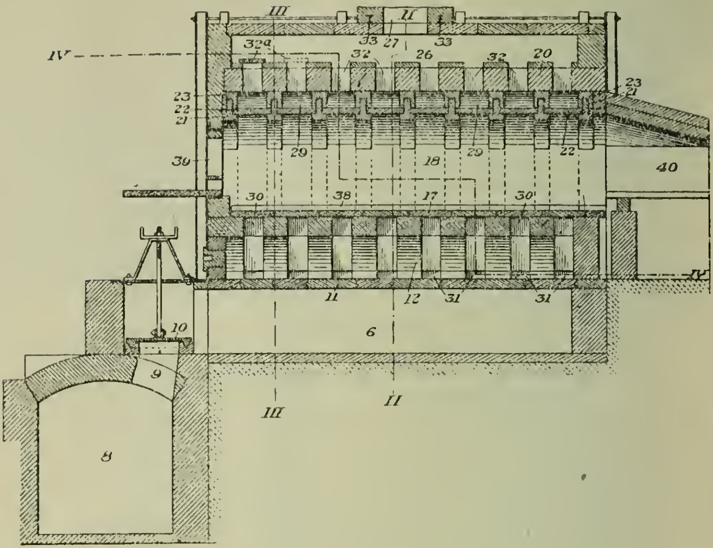


Fig. 159.

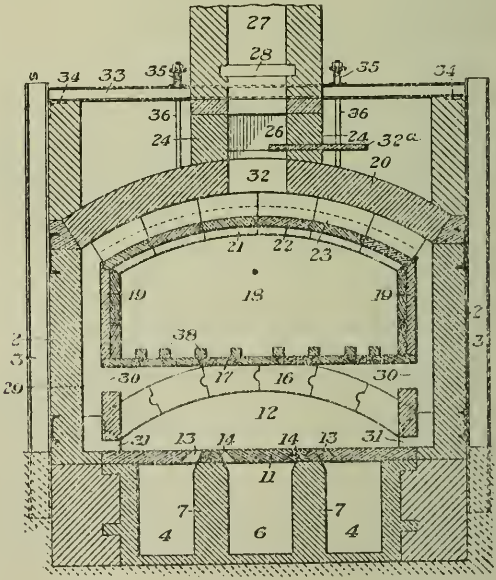


Fig. 160.

crown. Thus the burning gas is led from the combustion chamber, 12, right round the muffle before passing into the flue, 26, and dampers, 32*a*, above each port, 32, enable the temperature in the different portions of the muffle to be regulated. Longitudinal tiles, 38, within the muffle are used to cover the joints between the bottom tiles, 17, of the muffle, and may also serve for supporting the runway for the lehr pans. G. D.

VIII.—Chemical Analysis.

346. A Colorimetric Determination of Lead Dioxide in Litharge. Walter V. Morgan (*J. Ind. Eng. Chem.*, 1919, **11**, 1055).—The method had been found advantageous by the author in connection with rubber work, where it was important to know the amount of oxidising agent present. With slight modifications it would also be found applicable to the determination of oxidising agents in general when they occurred as an impurity with non-oxidising agents.

The procedure recommended was as follows. Five grams of litharge are boiled for a minute with a solution containing 2 grams of aniline hydrochloride dissolved in 10 c.c. of water and 5 c.c. of concentrated hydrochloric acid. The solution is then cooled to permit the separation of any lead chloride which has been formed, and filtered to remove lead chloride and any litharge which has not been dissolved. As the method depends upon the oxidising power of the dioxide, it is not necessary to convert all the litharge into lead chloride. The lead dioxide oxidises the aniline to aniline purple, the intensity of the colour being proportional to the lead dioxide content. Hence the filtrate is compared with standards made by adding definite amounts of lead dioxide to the above-mentioned solution. C. M. M.

347. The use of Nickel Crucibles for the J. Lawrence Smith Fusion in Determining Soil Potassium. Seth S. Walker (*J. Ind. Eng. Chem.*, 1919, **11**, 1139).—The scarcity and high price of platinum caused the author to investigate the possibility of substituting nickel for platinum crucibles when determining the potash value of soils by the Lawrence Smith method.

He found that the same result for soil potassium was obtained whether the soil was fused in a platinum crucible or a nickel one, but owing to the attack of the fusion mixture on the nickel crucible its life was short. C. M. M.

348. Electrometric Titrations, with special reference to the Determination of Ferrous and Ferric Iron. J. C. Hostetter and H. S. Roberts (*J. Amer. Chem. Soc.*, 1919, **41**, 9, 1337).—The authors described a method for the direct electrometric titration of ferrous iron with standard dichromate solution and investigations into the most suitable conditions desirable for the estimation. By this method, extremely minute quantities of ferrous iron could be accurately determined in the presence of a very large excess of ferric iron. A combination method was also described for the determination of total iron.

Electrometric titrations found many applications, including the determination of iron in optical glass, raw materials for optical glass making, and in glass pots. F. W. H.

349. The Determination of Zirconium by the Phosphate Method. G. E. F. Lundell and H. B. Knowles (*J. Amer. Chem. Soc.*, 1919, **41**, 11, 1801).—The method recommended for the estimation of zirconium was a modification of that suggested by Nicolardot and Reglade (*Compt. rend.*, 1919, **168**, 348; this Journal, 1919, Abs., p. 205).

The solution containing the zirconium was rendered acid by the presence of 20 per cent. by weight of sulphuric acid. The volume varied from 25 c.c. for small amounts (0·0005 gram ZrO_2) to 200 c.c. for larger amounts (0·01 gram ZrO_2). The temperature was raised to between 40° and 50°, and excess of ammonium phosphate added. The excess used was from ten to one hundred times the theoretical amount required by the ratio of Zr to P_2O_5, and the larger excess of the precipitant was necessary when small amounts of ZrO_2 were estimated. After addition of the ammonium phosphate, the mixture was allowed to stand in a warm place for two hours for complete precipitation of amounts of ZrO_2 exceeding 0·005 gram, and six hours or more for smaller amounts. The precipitate was then filtered while still warm, as much of the supernatant liquid as possible being decanted before transferring the precipitate to the filter. The precipitate was washed with a cold 5 per cent. solution of ammonium nitrate. Ignition was carried out in a partly covered platinum crucible, slowly until the paper was completely incinerated, and then very strongly over the blowpipe or a Meker burner.

The large excess of precipitant was necessary in order to obtain complete precipitation and a precipitate of normal composition. Washing with ammonium nitrate solution almost entirely overcame the tendency towards hydrolysis of the zirconium phosphate. Slow ignition prevented decrepitation of the precipitate and ensured complete combustion of the paper. The zirconium pyrophosphate was not hygroscopic, and the factor for conversion to ZrO_2 was 0·4632. By this method, zirconium was completely separated from aluminium, iron, chromium, cerium, and thorium, and also from titanium if sufficient hydrogen peroxide were added to the solution before precipitation of the zirconium. The addition of 10 c.c. of H_2O_2 had no adverse effect on the precipitation.

Historical notes and tables showing details of experiments dealing with the effect of varying conditions were also given.

F. W. H.

IX.—Machinery for the Working of Glass.

350. Method and Machine for Gathering Glass. K. E. Peiler, Hartford Fairmont Co. (U.S.A. Pat., December 9th, 1919, No. **1324464**. Filed December 4th, 1916, No. 134827).—The object of this machine is to feed glass from a tank or pot in portions of uniform size, consistency, and temperature, and to deliver them without any undue chilling.

A gathering head is mounted obliquely, and is thrust into the molten glass by the action of the cranked lever, 19 (Fig. 161), operated by a roller running in the cam groove, 22. At the same time, it is rotated so as to gather a mass of glass round it. This rotation continues until the cam disc through the lever, 19, has withdrawn the gathering head and brought the glass within a chamber heated either by the furnace flames or by separate jets. Here, with the rotation stopped, the glass is allowed to fall from the iron and is cut off by mechanically operated shears, which pass through openings, 7, in the opposite sides of the chamber. In order to follow the varying levels of glass in the pot or tank, the connection between the lever, 19, and the link can be varied by the screw, 24. This gives a longer or shorter stroke into the furnace, but always comes to the same discharge position. The gathering head is rotated through the splined gear wheel, 25, and the segmental rack, 31. In between these two is a ratchet wheel with a pawl, 30, which drives the gear wheel, 25, while the segment is moving in one direction only. The segment is made to reciprocate by the angle lever, 34, operated by a roller in the cam grooves, 36, which causes the segmental rack to move over its travel quickly in one

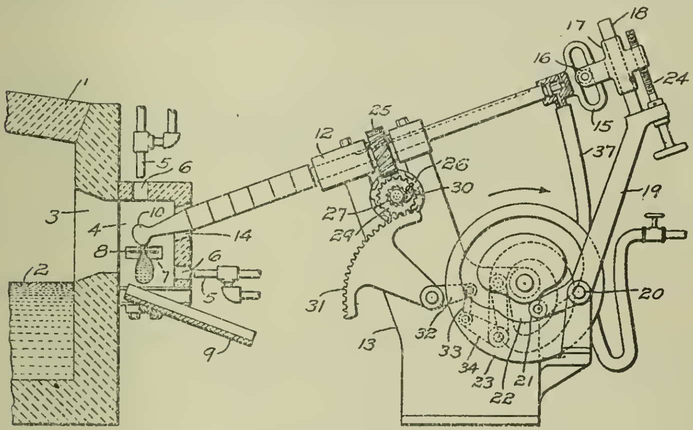


Fig. 161.

direction and slowly in the other; thus the gathering head is rotating for about two-thirds of each cycle.

The gathering head, which is of highly refractory material, and the iron stem are hollow, and overheating is prevented by blowing through a supply of compressed air from the flexible tube, 37.

S. E.

351. Glass Working Apparatus and Process. F. L. O. Wadsworth, Ball Bros. Glass Manufacturing Co. (U.S.A. Pat., July 29th, 1919, No. **1311474**. Filed April 24th, 1914, No. 834230).—This invention relates specifically to the arresting of the flow of glass from a gravity flow feeder, so that no lapping or piling up can occur during the time of mould movement. This effect is produced by severing the stream of molten glass at a point near the outflow orifice and then immediately subjecting the severed end and the sides of the stream to a momentary chilling. On removing the chilling means, the internal heat of the metal reheats the chilled skin, and the downward movement begins again.

The stream-arresting device consists of two reciprocating blocks of manganese steel or compressed carbon, with their adjacent faces shaped so as to form a downward-pointing cone when placed together, the base of the cone being approximately the same diameter as the stream of glass. When the glass is to be cut and chilled these blocks are brought together and a shear blade passed across the narrow end. The blocks can be immediately opened, and the chilled surface of the depending cone of glass will itself arrest the flow of glass from the tank for a short period. S. E.

352. Apparatus for Feeding and Delivering Glass. J. Schies (U.S.A. Pat., August 12th, 1919, No. **1312876**. Filed August 28th, 1914, No. 859099).—Molten glass is allowed to flow continuously over the edge of a lip or flow block extending from a doghouse built on to the nose of a tank. The glass may flow vertically downward into a mould or it may be diverted and carried back to the furnace.

When sufficient glass has flowed into the machine mould, a movement is imparted to the feedblock by which the stream of glass is severed, and the severed end directed towards a waste trough. Just as the next mould is being brought into position a reverse movement is imparted to the feed block, thus cutting the stream of glass at the upper end of the block, and directing the fresh stream into the mould now in position. The glass deflected to the waste trough is quickly returned to the furnace by buckets carried on an endless chain. On passing over the upper sprockets, the buckets are tilted by means of pins, and the glass is dumped on to an inclined spout leading into the furnace. S. E.

353. Process of, and Apparatus for, Drawing Glass. H. T. Bellamy and J. C. Smith, Western Electric Co. (U.S.A. Pat., May 13th, 1919, No. **1303452**. Filed December 26th, 1917, No. 208926).—The apparatus is specially designed to press thin glass vessels, such as small cylindrical glass vessels, and to avoid cracking due to excessive cooling, the ram and the die are in contact with the hot glass only for an exceedingly short time.

In operation, a very hot glob of glass is held in front of the pad, 90 (Fig. 162), which projects a very small distance through a die, 55. The pedal is then depressed, and the crank, 27, moves through one complete rotation, causing one full reciprocation of the rod, 41. This presses the round-ended ram, 47, into the glass, and when the glass separating the ram and the pad has been reduced to the desired thinness the pad is quickly withdrawn by the action of the rod, 104. The pad is held up to the ram just long enough to cause the glass to take a definite shape and to stiffen, but not long enough to cause it to crack. The ram, 47, continues to move forward and draws plastic glass from the bulk, 110, with it through the die. Towards the end of the stroke the sleeve, 49, begins to move forward, and as it fits accurately in the hole of the die, it shears off the plastic glass from that which has passed through the die on the ram. On the return stroke, the sleeve, 49, is held in position for some time by the pawl, 68, thus preventing the drawn glass from coming back with the ram. The temperature of the bulb as it is stripped from the ram is such that it is still soft, and to prevent deformation, it is allowed to fall on to an inclined surface covered with some soft material to break the force of the impact. In rolling down this surface, the bulb becomes sufficiently cool to retain its shape. The superfluous mass of glass encircling the sleeve is pushed off the end of the ram at the inward end of its stroke by the forked arm, 61. S. E.

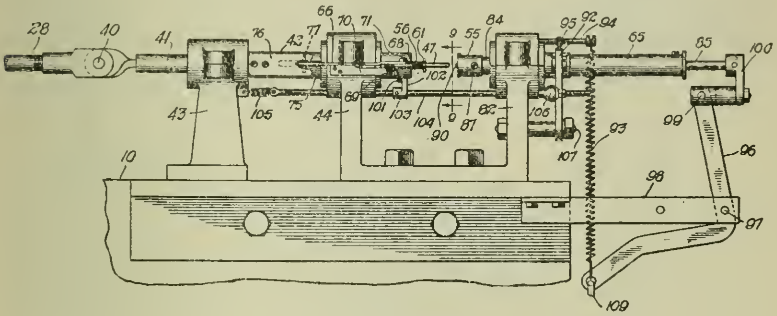


Fig. 162.

354. Process and Apparatus for Feeding Molten Glass. B. D. Chamberlin, Empire Machine Co. (U.S.A. Pat., December 2nd, 1919, No. **1323450**. Filed May 1st, 1916).—In this apparatus, molten glass flows from a tank through a discharge orifice, *M* (Fig. 163), terminating in a cavity in the floor of the tank. Within this cavity is a flow tube, b^7, which, being smaller than the cavity, leaves the annular air space, b^8. The upper end of the flow tube is reduced in size and apertured at m', to register with the orifice, m, the furnace structure. The top of the chamber forms a square shoulder surrounding the outlet end of the aperture, m', so that the thin stream of glass falls through the body of the chamber without clinging to the sides. The lower end of the chamber terminates in a water-cooled casting, one edge of which is formed into a shear element. The other shear element, H^3, is mounted on a shaft, F^3, immediately below the tube. Preferably this shear member is water-cooled, and has opposed cavity moulds for containing the gob of glass that is cut off. This cutting member is so timed that when the proper quantity of glass has accumulated in the cavity mould it is given a movement through 180°, thus shearing the downward-flowing stream of glass, and depositing the charge in a mould, E, below its pivotal point. In practice, the temperature of the space surrounding the chamber, b^9, and the hot glass flowing through the inside of the chamber, raise the temperature of the flow chamber sufficiently to prevent any appreciable cooling of the glass as it flows through the chamber, prior to its being severed. S. E.

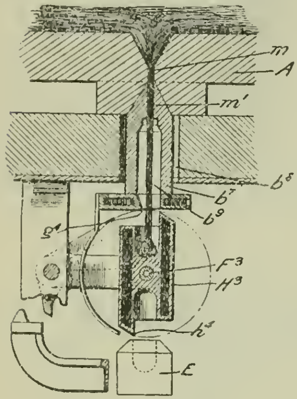


FIG. 163.

355. Apparatus for Feeding Molten Glass. W. A. LORENZ, HARTFORD FAIRMONT Co. (U.S.A. Pat., April 8th, 1919, No. **1300180**. Filed August 7th, 1917, No. 184874).—The object of this invention is to provide means for transferring gatherings of glass from a gathering apparatus to the moulds of various machines in a substantially horizontal plane, thus avoiding the necessity of bringing the moulds directly beneath the glass outlet.

The molten glass on being separated by shears in the usual manner falls into a trough, 25 (Fig. 164), with a suitable refractory lining. The trough has two or three curved branches, 11, according to the number of machines to be fed, each trough ending vertically above the machine moulds. Horizontal arms, 13, reciprocating on vertical shafts, 14, move alternately along these troughs, and have fitted at their free ends blocks

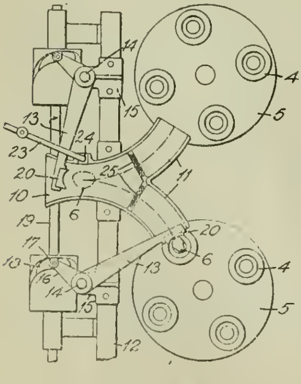


FIG. 164.

of carbon or other refractory material, 20. Thus, the gobs of glass as they fall are swept along the troughs and into the moulds.

The troughs may have flowing along them small streams of water, which is allowed to escape through small holes in the bottom just before the end of the trough is reached. The pusher arms are operated by rolls, 17, running in cam grooves, 18, in drums rotating on a horizontal axis, 19, and mounted underneath the rocker shafts. S. E.

356. Blowing Large Bottles, Carboys, and the Like. J. Rau (U.S.A. Pat. No. **1292051**, January 21st, 1919. Filed September 28th, 1916. No. 122751).—Relates to a means of blowing by machine large bottles such as carboys and the like of 5 to 15 gallons capacity. The invention consists in forming the parison of the same length as the finished articles, so that during the final blowing the parison does not elongate, but spreads laterally until it fills the finishing mould. In applying the process to a machine, the parison mould, 10, Fig. 165, has a movable bottom, 16, which can be raised or lowered by a rod, 19, connected with the piston of an air- or liquid-pressure cylinder, 21, secured below the rotary table, 17, of the machine. An adjustable stop, 25, on the rod, 19, limits the upward movement of the mould bottom. In use, the mould bottom is raised and the mould is filled with metal, which is pressed by a plunger, 15, to form the ring of the bottle and the

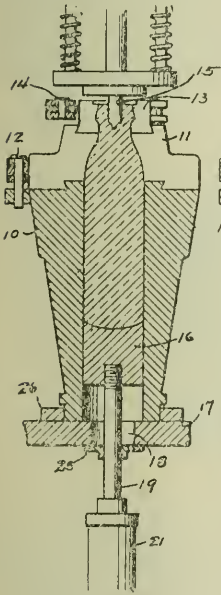


Fig. 165.

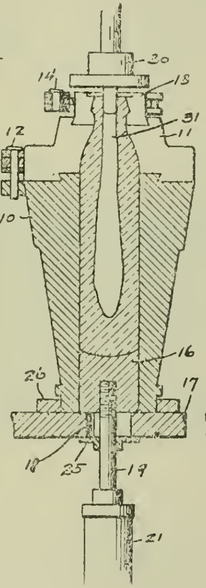


Fig. 166.

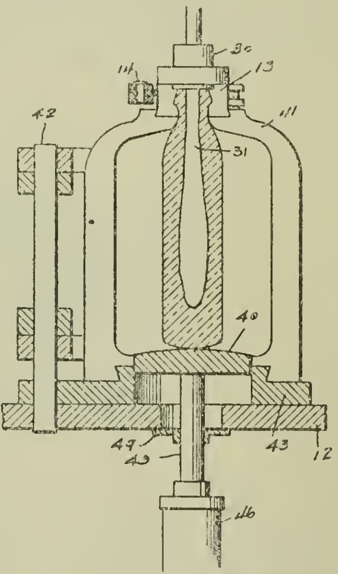


Fig. 167.

mouth opening. Air is next introduced from a blowhead, 30, Fig. 166, the mould bottom, 16, being allowed to descend at the same time, so that the parison elongates as shown, the final length being approximately that of the finished bottle. The parison is then transferred to a finishing mould, 41, Fig. 167, and a movable bottom, 40, raised to support the bottom of the parison and prevent it from elongating. Thus, during the final blowing, the parison expands laterally until it fills the mould. G. D.

357. Pressed Glass. J. H. Groth (U.S.A. Pat. No. **1290738**, January 7th, 1919, Filed October 6th, 1917, No. 195095).—Relates to means for pressing glass articles having recesses or apertures, such as holders for cut flowers. The invention consists in providing the press plug with pins to form the apertures, and in so constructing this plug that when it is lifted from the mould body, the pins are withdrawn from the glass before the plug begins to move upwards. The stem, 1, of the plug has a flange, 2, formed on its lower end, to which a disk, 3, is secured. Pins, 5, pass through holes in the disk and their heads are clamped between the disk and the stem. The plug, 9, is formed with a recess, 8, in which the disk, 3, slides, and is also provided in its lower portion with apertures, 10, through which the pins, 5, slide. A retaining ring, 13, prevents the disk, 3, from being lifted out of the plug, but permits them to move relatively to one another, a spacing washer, 12, being seated in the lower part of the recess to regulate the amount of the relative movement. The mould body, *A*, and the ring, *B*, are constructed as usual. In use, a gather, *G*, is pressed as usual, but when the plug is raised, the first effect is to loosen the pins, 5, from the glass, the stem moving upwards until the flange, 2, contacts with the ring, 13. Continued movement of the stem then lifts the plug from the mould. G. D.

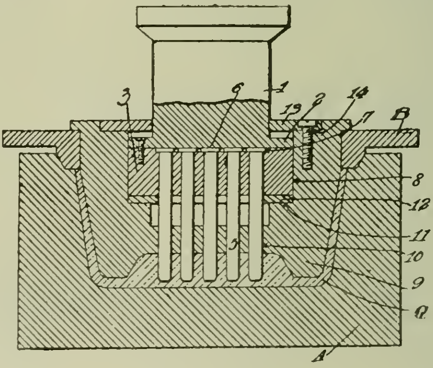


Fig. 168.

358. Machinery for Production of Pressed Glass. P. Ebeling (U.S.A. Pat. No. **1297122**, March 11th, 1919. Filed February 14th, 1918. No. 217278).—Relates to a mould for pressing prism pendants, 9, Fig. 169, such as are used for chandeliers, the supporting wires or pins, 8, being inserted during the pressing operation. A four-part mould body, 1, Fig. 170, has moulding spaces, 2, the plug, 3, having corresponding spaces. The body, 1, has an annular recess, 4, for the reception of a ring, 5, which has

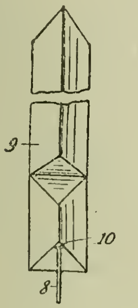


Fig. 169.

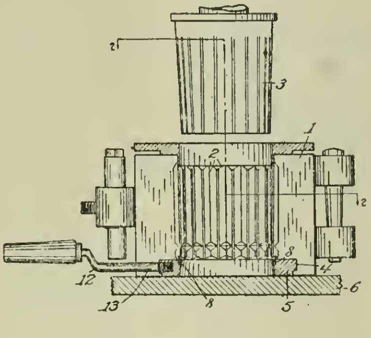


Fig. 170.

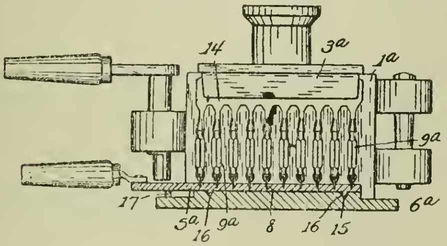


Fig. 171.

a circular row of perforations in which the pins are inserted. Thus the metal is pressed into a cylinder composed of prisms united by a thin fin or web of glass, which is broken away, the rough edges of the prisms being afterwards ground. In a modification, shown in section in Fig. 171, a two-part mould body, 1*a*. is used, the moulding spaces, 9*a*, extending downwards from the space, 14, for the surplus metal. The pins, 8, are inserted in a straight supporting bar, 5*a*, which is held in a space in the lower part of the mould body.

G. D.

359. A New Form of Mechanical Boy. P. Wecht (U.S.A. Pat. No. **1300066**, April 8th, 1919. Filed April 6th, 1918. No. 227105).—In a mechanical boy, the support, 19, of the mould halves, 3, is secured to vertical racks, 5, which engage toothed segments, 9, secured on a shaft, 10. A pinion, 11, also secured on the shaft, 10, is engaged by a rack, 12, attached to a pedal, 15. Thus by depressing the pedal the mould may be raised out of the water in the tank, 1. The mould halves are pivoted to a post in the support, 19, and are connected by links to a sliding rod, 22, a spring, 24, being arranged to keep the mould halves open. The mould is closed by a second pedal, 31, which is secured to a vertally marable member, 27, having an inclined surface, 27*a*. When the mould is raised, depression of the pedal, 31, causes the member 27, to engage the end of the rod, 22, and slide it forward, thus closing the mould. The bottom, 36, of the mould may be carried by a fixed support, 32, so that it co-operates with the mould halves. The bottom may be revolvable on its support, and may bear a design, a star, for instance, which it may be desired to impress on the ware, the bottom being free to rotate with the article as it is turned in the mould. Alternatively, a fixed bottom may be carried by the support, 19. G. D.

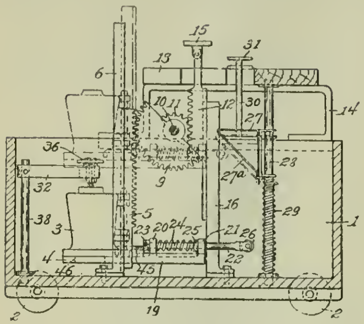


FIG. 172.

360. A Tube Drawing Machine. F. G. KEYES (U.S.A. Pat. No. **1291921**, January 21st, 1919. Filed February 18th, 1913. No. 749124).—Relates to a "means of drawing a tube of any material admitting such treatment in such a manner as to ensure the formation of a tube having a uniform external diameter and a central opening substantially regular." The material, 3, which may be glass or quartz, is liquefied in a crucible, 2, and a tube of suitable material is dipped into the liquid and drawn upwards through a heat-resisting die, 5, a blower, 11, supplying air to the central tube in order to maintain the diameter while drawing. Outside the die, the tube, 10, is cooled by a closed annular holder, containing boiling metal, 7, such as mercury, which is connected to a condensing chamber, 9. The crucible may be of tungsten, and a

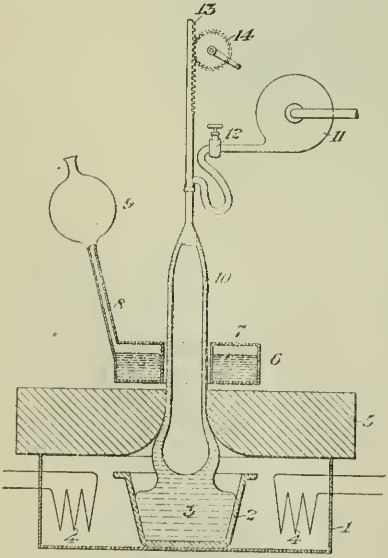


FIG. 173.

coating of tungsten may also be applied to the lower side of the die, 5. G. D.

361. Paste Mould Machine. F. W. Stewart (U.S.A. Pat. No. **1294319**, February 11th, 1919. Filed October 27th, 1915. No. 58218).—Relates to a "paste mould" machine, that is, a machine which receives a pipe with a marvered parison and completes the blowing in a pasted mould, the article being turned in the mould while being blown. The principal improvement constituting the present invention appears to be the means for cooling the mould. The machine comprises a table, 2, for supporting the moulds, 67, sprayers, 64, for cooling the moulds, and a pillar, 4, for supporting the cylinders, 8, which control the nozzles, 15, that engage the blowpipes, 76. Metal having been gathered in the pipe, 76, and marvered, the pipe is placed in the supports, 77, and a handle, 41, turned. Air is thus admitted to cylinders, which close the mould, 67, about the suspended parison, and is also admitted to a cylinder, 8, which forces the nozzle, 15, down in the pipe and commences to blow the article in the mould. At the same time an electric motor, 34, operating through gearing, oscillates the nozzle, 15, and therefore the pipe, 76, so that the article is turned in the mould while being blown. The turning of the handle, 41, also admits air to a cylinder, 49, and raises a spray pipe, 64, within the second mould, as shown. As the spray pipe reaches its position, a valve trigger, 61, engages a fixed stop and admits water, which is sprayed over the inside of the mould. When the article is blown, the operator moves back the handle, 41, and the air pressure opens the mould, raises the nozzle, 15, and lowers the spray pipe from the other mould. G. D.

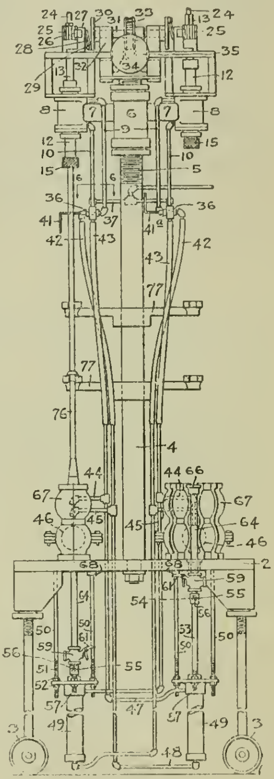
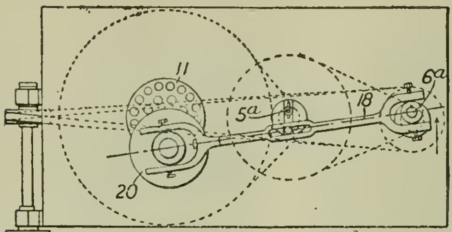


FIG. 174.

362. Grinding and Polishing Lenses. W. J. Druiff and Anglo-American Optical Co. (Brit. Pat. No. **123270**, July 30th, 1918, No. 12423).—Apparatus for grinding and polishing lenses comprises a table or support, 11 (Fig. 175), for the lenses,

a revolvable tool, 20, mounted by means of a universal joint at one end of an horizontally-disposed arm, 18, the opposite end of which is engaged by a crank-pin, 6^a, on a vertical shaft, while, intermediate between its ends, the arm is slotted to engage a crank-pin, 5^a, on another shaft. The apparatus shown is for treating spherical lenses, and the table is mounted on a vertical shaft. The shaft of the crank-pin, 5^a, runs at a lower speed than the other crank-shaft, and the shaft of the table at a still lower speed. The cranks are preferably adjustable in throw. For cylindrical lenses, a guided table is employed. For "figuring," a modified arrangement (Fig. 176) is used; the arm, 18, does not carry the tool directly, but engages, by a pin-and-slot connection, with an upper arm, 22^c, which carries the tool at one end and engages at the other with a crank-pin, 22, carried by, but angularly displaced from, the first pin, 6^a.
H. G. C.

Fig. 175.



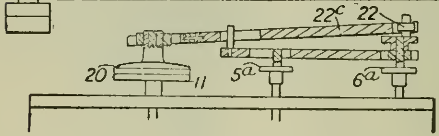


Fig. 176.

JOURNAL

OF THE

SOCIETY OF GLASS TECHNOLOGY

Indexes for 1919

(**P.**, Proceedings ; **T.**, Transactions ; **A.**, Abstracts)

INDEX OF NAMES

Acree, S. F., **A.**, 105.
Advisory Research Council, **P.**, 9.
Ainger, R., **P.**, 22.
Alatine, E. van, **A.**, 41.
Alexander, G. E., **P.**, 21, 31.
Allen, B. J., **P.**, 13, 22, 23 ; **T.**, 78 ; **A.**, 58, 59.
Allen, E. T., **A.**, 15, 68, 103, 104, 235.
Alliata, G., **A.**, 200.
Allison, V. C., **A.**, 104.
Allwood, S. J. R., **A.**, 135.
Ambronn, R., **A.**, 101.
American Bottle Co., **T.**, 183.
American Ceramic Society, **P.**, 8, 27, 49
Amsler-Morton Co., **T.**, 180.
Andersen, O., **A.**, 230.
Anderson, E., **A.**, 219.
Anderson, R. P., **A.**, 208.
Anglo-American Optical Co., **A.**, 281.
Appert, L., **A.**, 168.
Archibald, E. H., **A.**, 205.
Arndt, K., **T.**, 46.
Arnold, H., **A.**, 61.
Ashley, —., **T.**, 23.
Asquith, H. H., **P.**, 21.
Asquith, M., **P.**, 21, 31.
Astley, A., **A.**, 90.
Aston, F. W., **A.**, 106.
Atkinson, J. S., **P.**, 49 ; **T.**, 148.
Aubert, A. M., **A.**, 131.
Auerbach, **A.**, 175.
Auger, V., **A.**, 167.
Avis, B. D., **A.**, 44.

Bacon, R. F., **A.**, 182.
Bader, A., **A.**, 73.
Bagley, D., **A.**, 64, 65.
Bagley, S. B., **P.**, 21.
Bailey, W. A., & Co., **T.**, 186.
Baird, D. H., **A.**, 21.
Baird & Tatlock, **T.**, 253.
Bajda, J. J., **A.**, 41.
Baker, G. F., **P.**, 33.
Baker, T. Y., **A.**, 110.
Baker Clay Co., **A.**, 66.
Ball Bros'. Glass Co., **A.**, 274.
Banks, W., **A.**, 134.
Barker, W. R., **P.**, 21.
Barrett, M., **P.**, 10.
Barringer, L. E., **A.**, 188.
Batchelor, H., **A.**, 137.
Bateson, E., **P.**, 54.
Baur, C. H. von, **A.**, 139.
Bausch & Lomb Co., **T.**, 192 ; **A.**, 187.
Beatson, Clark & Co., **P.**, 4 ; **A.**, 209,
Beesley, F. A., **P.**, 33.
Beecher, M. F., **A.**, 185.
Beilby, G. T., **A.**, 29.
Bell, C. A., **A.**, 177.
Bellamy, H. T., **A.**, 164, 274.
Benjamin, G. H., **A.**, 196.
Bennett, W., **A.**, 196.
Bergius, H., & Co., **A.**, 8.
Bergman, W. D., **A.**, 93.
Berkeley Glass Sand Co., **T.**, 72.
Berkshire Glass Sand Co., **T.**, 72.
Berndt, G., **A.**, 26, 48.
Berney-Bond Glass Co., **T.**, 189.
Berridge, D. P., **P.**, 33.
Berthelot, M., **A.**, 24, 25.

Bigot, A., **A.**, 121.
Biot, —., **T.**, 257.
Biram, R. S., **P.**, 1, 21.
Blaw-Knox Engin. Co., **T.**, 176.
Bleininger, A. V., **A.**, 123, 230, 236.
Boam, F. J., **P.**, 21, 23.
Bock, J. C., **A.**, 105.
Bockman, O. C., **A.**, 139.
Boeck, P. A., **T.**, 202, 216, 220.
Bole & Howe, **A.**, 186.
Boswell, P. G. H., **P.**, 4, 21 ; **T.**, 72.
Böttcher, Prof., **A.**, 244.
Bowen, N. L., **A.**, 13, 20, 172.
Bradford, S. C., **T.**, 282.
Bradley, F. E., **P.**, 22.
Branscomb, P., **P.**, 13.
Branson, F. H., **P.**, 51 ; **T.**, 249.
Branson, F. W., **P.**, 17, 21, 31, 32, 33, 51 ; **T.**, 249 ; **A.**, 23.
Brit. Cyanides Co., **A.**, 4.
British Hartford-Fairmont Syndicate, T., 184, 188.
Brit. Labor. Ware Assn., **P.**, 33 ; **T.**, 135, 249, 250.
Brit. Opt. Inst. Manftrs. Assn., **A.**, 25.
Brit. Thomson-Houston Co., **A.**, 215.
Brockbank, C. J., **A.**, 229.
Brooke, F. H., **P.**, 10.
Brown, G. H., **A.**, 117.
Brown, J. H., **A.**, 134.
Brown, W. A., **P.**, 15.
Bruner, L. N., **A.**, 149.
Buchanan, J. Y., **A.**, 26.
Buckeye Clay Pot Co., **T.**, 193.
Buffalo Scale Co., **T.**, 172.
Burch, G. J., **A.**, 45.
Burdin, W., **A.**, 139.
Burdins Ltd., **A.**, 139.
Bureau of Standards, **T.**, 192.
Burgess, C. H., **A.**, 231.
Burtles, Tate & Co., **P.**, 2.
Butler, W., **P.**, 13, 21 ; **T.**, 91.
Butler, W. W., **A.**, 90.

Campbell, E. D., **A.**, 38.
Carpenter, C., **P.**, 32.
Cauwood, J. D., **P.**, 4, 20, 23 ; **T.**, 129, 135, 228, 266 ; **A.**, 20.
Ceramic Society, **T.**, 3 ; **A.**, 113, 127.
Chalmers, S. D., **A.**, 45.
Chamberlain, B. D., **A.**, 275.
Chance, K. M., **P.**, 32, 33 ; **A.**, 3.
Chatelier, H. Le, **T.**, 116–125, 201, 202 ; **A.**, 120, 141, 237.
Chattaway, F. D., **A.**, 108.
Chaundy, T., **A.**, 45, 47, 109.
"Chem.-Zeit.," **A.**, 44.
Chowning Regulator Corp., **T.**, 174, 199.
Chree, C., **A.**, 177.
Clark, F. G., **P.**, 21, 23, 27, 31.
Clarke, G. W., **P.**, 19, 21.
Clarke, J. R., **P.**, 20, 23 ; **T.**, 228, 260.
Clarke, J. V., **A.**, 113.
Clarke, W. A., **A.**, 113.
Clayton, J., **A.**, 212.
Clegg, A. E., **A.**, 78, 211.
Clement, J. K., **A.**, 104.
Coad-Pryor, E. A., **P.**, 9, 24 ; **T.**, 93, 104, 105, 216, 220–22 ; **A.**, 127.
Cobb, J. W., **P.**, 8, 9, 21, 49, 51 ; **T.**, 160, 161, 201.
Collie, J. N., **T.**, 255.
Collinson, A. H., **T.**, 69.
Conklin, O. E., **A.**, 255.
Connolly, J., **P.**, 2, 4, 8, 9, 21, 23, 31, 49, 51, 53–57 ; **T.**, 23, 147, 166, 199.
Conservatoire National des Arts et Metiers, **A.**, 121.
Cooksedge, H. E., **A.**, 160.
Coppee, E., **T.**, 201.
Corbett & Co., **T.**, 214.
Cossor, F., **P.**, 54.
Cotterell, F., **A.**, 215.
Cottrell, F. G., **A.**, 107.
Coupeau, **T.**, 201.
Cox, C. F., **A.**, 78.
Cox Machine Co., **T.**, 186.
Crittenden, E. C., **A.**, 50.
Crockwood, C., **A.**, 135.
Crookes, Sir Wm., **P.**, 21, 29 ; **A.**, 30.
Crowther, J. H., **P.**, 27, 30 ; **T.**, 136.

Dager, G. C., **A.**, 146.
Damour, **T.**, 201.
Dauphin, L., **A.**, 188.
Davidson, J. H., **P.**, 8, 9, 13, 23, 49, 51 ; **T.**, 92, 135, 159, 222, 248, 266, 271, 275.
Davidson, T., **P.**, 21.
Davies, **P.**, 9.
Davis, C. W., **A.**, 181.
Davis, H. N., **A.**, 194, 201.
Davisson, B. S., **A.**, 108.
Day, A. L., **T.**, 216.
Dean, T. A., **A.**, 179.
Delegacy for Glass Research, **P.**, 9 ; **T.**, 133.
Denk, F. J., **A.**, 263.
Dept. Scient. Indust. Research, **P.**, 17 ; **T.**, 93, 133.
Dewitt & Herz, **T.**, 267.
Dimbleby, Miss V., **P.**, 23, 31 ; **T.**, 135.
Dingley, C. S., **A.**, 219.
Directorate of Chem. Inspection, **T.**, 69.
Dixon, H. L., **T.**, 175, 177, 178.
Dixon-Nuttall, F. R., **P.**, 30.

Dowse, G., **P.**, 54.
Doyle, G. R., **A.**, 204.
Dralle, R., **A.**, 221.
Drude, **A.**, 35.
Druiff, W. J., **A.**, 44, 281.
Dufton, S. F., **A.**, 42.
Dunkley, W. A., **A.**, 50.
Durand, E., **A.**, 144.
Duroglass Ltd., **T.**, 214, 254.
Dutt, E. E., **A.**, 94.
Dutt, P. C., **A.**, 94.

Ebeling, P., **A.**, 278.
Edward, F., **P.**, 2 ; **T.**, 25.
Edwards, M. H., **P.**, 13 ; **T.**, 91.
Egloff, G., **A.**, 51.
" Electrician," **A.**, 50.
Elsden, A. V., **T.**, 52.
Emery, W., **A.**, 118.
Empire Machine Co., **A.**, 275.
English, S., **P.**, 1, 4, 21, 23 ; **T.**, 34, 125, 135, 138, 238, 256, 258, 278 ; **A.**, 23.
Ensign Instrument Co., **T.**, 181.
Esslemont, A. S., **P.**, 1, 15.
Etchells, H., **A.**, 194.

Fairbanks Scale Co., **T.**, 172.
Farnley Iron Co., **T.**, 214.
Fearnsides, W. G., **P.**, 21, 49 ; **T.**, 162.
Federal Council, **P.**, 17.
Federal Glass Co., **T.**, 188.
Feild, A. L., **T.**, 46, 47, 281 ; **A.**, 37, 38.
Fenner, C. N., **T.**, 116 ; **A.**, 17, 19, 95, 163.
Ferguson, J. B., **T.**, 124, 125 ; **A.**, 17, 19, 186, 239, 240.
Ferry, T. W., **P.**, 49 ; **T.**, 164, 249.
Fieldner, A. C., **A.**, 72.
Filon, L. N. G., **A.**, 110, 111, 112.
Findley, A. E., **A.**, 206.
Firth, Miss E. M., **P.**, 27 ; **T.**, 135.
Fischer, F., **A.**, 30.
Fisher, E. E., **T.**, 147.
Fisher, H. L., **A.**, 40.
Flear, C. W., **A.**, 90.
Fleming, A. P. M., **P.**, 21.
Fletcher, T. W., **A.**, 134.
Fletcher, Russell & Co., **A.**, 134.
Ford Motor Co., **P.**, 2 ; **T.**, 24.
Forster, J., **A.**, 157.
Forster, W., **A.**, 147.
Foster, Sir H. S., **P.**, 9 ; **T.**, 133.
Fox, H. B., **A.**, 90.
Fox, J. C., **P.**, 23.
Fox, J. J., **P.**, 33.
Foxon, J. E., **P.**, 21, 23.
Francart, H., **A.**, 198.
Frazier, C. E., **A.**, 267.
Frederick, C. W., **A.**, 250.
Freeth, F. A., **A.**, 160.
French, J. W., **P.**, 21.
Frew, H. K., **T.**, 69.
Frink, R. L., **P.**, 49 ; **T.**, 163, 173, 174, 242 ; **A.**, 165.
Fritz, H., **A.**, 223.

Gard, J. S. F., **A.**, 64.
Gardner, W. J., **P.**, 10, 23, 51 ; **T.**, 218, 221.
Garnett, J. C., **P.**, 2.
Garnett, J. C. M., **A.**, 31, 33.
Gasch, A., **A.**, 179.
Gates, E. D., **A.**, 262.
Geijsbeek, S., **A.**, 59.
Gelstharp, F., **A.**, 18, 223, 224, 227.
General Electric Co., **A.**, 215.
German Potash Synd., **A.**, 7.
Ghijsen, H. C., **A.**, 191.
Gibbons, W. M., **P.**, 10, 22.
Gibson, K. S., **A.**, 252.
Gifford, J. W., **A.**, 44.
Giles, A. S., **P.**, 54.
Gilmore, R. E., **A.**, 52.
Glass Bottle Manftrs. Assn., **T.**, 134.
Glass Research Assn., **P.**, 10, 21, 49 ; **T.**, 134.
Glazebrook, Sir R., **P.**, 24.
Glaziers Co., **P.**, 9.
Glenshaw Glass Co., **T.**, 187.
Goldreich, S., **A.**, 16.
Goltz, M. A., **A.**, 49.
Gorton, A. F., **A.**, 115.
Gowlland, H., **A.**, 88, 89.
Granger, A., **A.**, 124.
Gray, A. W., **A.**, 47.
Gray, J., **A.**, 150.
Greaves, H. A., **A.**, 194.
Greinacher, H., **A.**, 30.
Griffin, J. R., **P.**, 33.
Griffiths, Mrs. C. H., **A.**, 179.
Groth, J. H., **A.**, 278.
Grull, W., **A.**, 11.
Guertler, **A.**, 232.
Gurevich, L. J., **A.**, 207.
Gwosdz, **A.**, 51.

Habasian, Y., **A.**, 205.
Hadfield, Sir R., **P.**, 32.
Halberg-Beth, **A.**, 4.
Hall, I., **A.**, 62.
Hamor, W. A., **A.**, 182.
Hardy, W. B., **A.**, 234.
Hartford-Fairmont Co., **T.**, 183, 184, 188 ; **A.**, 141, 273, 276.
Harvey, D., **P.**, 33.
Harvey, E. W., **A.**, 135.
Harwood, H. F., **T.**, 78.
Heath, Sir F., **P.**, 21, 22, 23.
Hebbeler, K., **A.**, 9.

Heningk-Lorenz, **A.**, 11.
Henning, F., **A.**, 140.
Hebbard, P. L., **A.**, 202.
Hilger, Ltd., **T.**, 61.
Hill, J. G., **T.**, 92.
Hodgson, M. B., **A.**, 251.
Hodkin, F. W., **P.**, 23, 27, 51 ; **T.**, 135, 253, 266, 275.
Hodsman, H. J., **P.**, 51 ; **T.**, 201.
Hofman, H. O., **A.**, 225.
Hohlbaum, **A.**, 221, 241.
Holborn, **T.**, 201, 202 ; **A.**, 141.
Holdcroft, A. D., **A.**, 229.
Holland, J., **P.**, 51 ; **T.**, 218, 221.
Hollis, A., **A.**, 133.
Holt, A., **A.**, 231.
Hope, G. F. W., **A.**, 93, 159.
Hopkinson, E., **P.**, 12.
Hostetter, J. C., **A.**, 186, 271.
Houdaille & Triquet, **T.**, 155, 164.
Hough, G. J., **A.**, 43.
Houldsworth, H. S., **T.**, 214.
Houston, R. A., **A.**, 34.
Howard, D. L., **P.**, 32.
Howard, G. E., **A.**, 154.
Huber, F. W., **A.**, 7.
Hurez, E., **A.**, 198.
Hursh, R. K., **A.**, 66.

Icknield Glass Works (Oslers), **P.**, 13.
Illum. Eng., Soc. of, **P.**, 17.
Ingersoll-Rand Co., **T.**, 184.
Instit. of Chem., **P.**, 24.
Ives, H. E., **A.**, 251.

Jackson, Miss A. M., **P.**, 16, 23.
Jackson, C. E., **A.**, 188.
Jackson, Congreve, **P.**, 13, 21.
Jackson, Sir H., **P.**, 9, 32 ; **T.**, 283.
Jackson, T., **A.**, 211.
Jacquerod, **A.**, 24.
Jäger, F. M., **A.**, 234.
James, C., **A.**, 126.
Jameson, A. B., **A.**, 205.
Jenkinson, S. N., **P.**, 2, 8, 9, 10, 20, 21, 27, 31, 49, 53–57 ; **T.**, 26, 50, 144, 164, 214, 220, 248.
Johnston, H. J. C., **P.**, 10.
Jones, G. W., **A.**, 208.
Jones, H. S., **T.**, 52.
"Journ. Ind. Eng. Chem.," **A.**, 28, 161.
Juniata White Sand Co., **T.**, 72.

Kadow, A., **A.**, 82.
Kali Syndicate, **A.**, 6.
Kanolt, C. W., **A.**, 261.
Kaye, G. W. C., **T.**, 204.
Keith, G., **A.**, 178, 192.
Keith, J., **A.**, 178, 192.
Keith, T. E., **A.**, 71.
Kellner, H., **A.**, 250.
Kempton, Messrs., **T.**, 70.
Kennedy, H. A., **A.**, 63.
Kenworthy, J., **P.**, 15.
Kestner, P., **A.**, 5.
Kettel, F. J., **A.**, 179.
Keuffel, C. W., **T.**, 192.
Keuffel & Esser Co., **T.**, 192.
Keuren, W. L. Van, **A.**, 255.
Keyes, F. G., **A.**, 280.
King, C. A., **A.**, 42 ; **T.**, 214.
King, Major, H. C., **P.**, 10.
Kitson, T. B., **A.**, 144, 192.
Klooster, H. S. van, **A.**, 234.
Knoblauch, H., **A.**, 10.
Knote, J. M., **A.**, 223.
Knowles, H. B., **A.**, 272.
Koenig, R., **A.**, 244.
Koeningsberger, J., **A.**, 40.
Kollmorgen, F., **A.**, 249.
Konek-Norwall, von F., **A.**, 7.
Kunkel, **A.**, 221.
Kurlbaum, **A.**, 141.

Ladou, A., **A.**, 79.
Langwell, E. H., **A.**, 144.
Larson, J. P. A., **A.**, 93.
Lax, F., **P.**, 19, 21.
Leblanc, **T.**, 91.
Lecrenier, S., **A.**, 175.
Lee, H., **A.**, 45.
Lenher, V., **A.**, 72.
Libbey Glass Co., **T.**, 129.
Libbey Owens Window Glass Co., **T.**, 171, 190, 196, 198.
Lindley, J., **A.**, 57.
Lindo-Gladding, **A.**, 71.
Lindsay Light Co., **A.**, 181.
Link-Belt Co., **T.**, 171.
Lliteras, J. M., **A.**, 7.
Lockwood, Z. V., **A.**, 209.
Longstaff, J. P., **P.**, 48.
Loomis, G. A., **A.**, 55.
Lorenz, E. H., **A.**, 141.
Lorenz, W. A., **A.**, 276.
Louis, Prof., **P.**, 32.
Low, A. R., **A.**, 49.
Luckiesh, M., **A.**, 33, 255.
Lummis, C. W., **A.**, 256.
Lundell, G. E. F., **A.**, 272.
Lynch Glass Machine Co., **T.**, 185, 186, 188.
Lyttleton, W. R., **A.**, 157.

MacArdle, D. W., **A.**, 177.
Macbeth Evans Glass Co., **T.**, 129, 192.
McBride, R. S., **A.**, 50.
McCauley, R. E., **A.**, 150, 153.
McCauley, W. M., **T.**, 185.
McCoy, T. J., **A.**, 213.

McDowell, J. S., **A.**, 60.
McHargue, J. S., **A.**, 178.
McKerrow, C. A., **A.**, 16.
McLeod, A. R., **A.**, 43.
Malisoff, W., **A.**, 51.
Mallinson, G. A., **P.**, 33.
Mansfield, F. G., **P.**, 15.
Marks, E. C. R., **A.**, 83.
Marsh, G., **A.**, 127.
Martin, L. C., **A.**, 47, 179.
Maxon Premix Burner Co., **T.**, 178.
Meade, R. K., **A.**, 72.
Mees, C. E. K., **A.**, 250.
Meighan, M. H., **A.**, 208.
Mellor, J. W., **P.**, 8 ; **T.**, 81, 201 ; **A.**, 53, 118, 184.
Merrill, H. B., **A.**, 72.
Merwin, H. E., **T.**, 124, 125 ; **A.**, 239, 240.
Meyer, H. C., **A.**, 124.
Miller, Edward, **T.**, 185, 188, 197.
Miller, W. J., **T.**, 185, 187, 189, 197.
Mills, J. D., **P.**, 2 ; **T.**, 14, 27.
Ministry of Munitions, **P.**, 7, 9, 17, 32.
Minton, R. H., **A.**, 52.
Mirrlees-Leblanc, **T.**, 91.
Molineaux, Webb & Co., **P.**, 2.
Moore, T. A., **P.**, 33.
Moorshead, T. C., **P.**, 54.
Morey, G. W., **A.**, 100, 163.
Morgan, W. V., **A.**, 271.
Morrison, S. W., **P.**, 1, 9, 10, 11, 21, 31.
Morton, B. F., **A.**, 269.
Mostowitsch, W., **A.**, 225.
Mott, W. R., **A.**, 259.
Mottram, G. W., **A.**, 120, 184.
Muirhead, Miss C. M. M., **P.**, 4, 23 ; **T.**, 129, 228.
Muller, C. E., **T.**, 267.
Müller, B., **A.**, 221.
Müller, W. J., **A.**, 40.
Munro, R. W., Messrs., **P.**, 54.
Mylius, **T.**, 55, 56.

Naamlooze Vennootschap Vitrite Works, **A.**, 191.
Nat. Phys. Lab., **P.**, 24, 33, 42–47 ; **T.**, 95, 115.
Nelson & Co., William, **P.**, 2.
Nesbitt & Bell, **A.**, 258.
Neumann, B., **A.**, 39.
Nicolardot, P., **A.**, 205.
North Lincoln. Iron Co., **A.**, 4.
Nutting, P. G., **A.**, 252, 253, 254.
Nyman, E., **A.**, 204.

Olsen, S. D., **A.**, 149.
O'Neill Machine Co., **T.**, 184, 188, 197.
Optical Society," **P.**, 31.
Optical Society of America," **P.**, 31.
" Optician," **A.**, 48.
Osler, J. A., **P.**, 2 ; **T.**, 26.
Osler, Messrs., **T.**, 256.
Ostwald, **T.**, 118.
Ottawa Silica Co., **T.**, 72, 73, 78.
Owens Bottle Co., **T.**, 175, 179, 182, 183, 195, 199.

Parker, H. H., **A.**, 42.
Peck, A. B., **A.**, 190.
Peddle, C. J., **P.**, 8, 21, 23, 24, 31, 49 ; **T.**, 249.
Peeters, A. F., **A.**, 191, 192.
Peiler, K. E., **A.**, 141, 273.
Pelletan, A., **A.**, 110.
Pelouze, **A.**, 221.
Periscopes & Hyposcopes, Ltd., **P.**, 15.
Perrot, **A.**, 24.
Perry, G. H., **T.**, 69.
Philadelphia Textile Machinery Co., **T.**, 194.
Phillips, A. J., **A.**, 61, 186.
Phillips, C. E. S., **A.**, 29.
Phillips, L. W., **A.**, 35.
Pilcher, R. B., **P.**, 53.
Pilkington Bros., **P.**, 12 ; **A.**, 151, 156.
Pitt, H. H., **T.**, 185, 190.
Pittsburgh Plate Glass Co., **T.**, 192.
Pockels, F., **A.**, 111.
Powell, H. J., **P.**, 21.
Preston, E., **T.**, 266.
Purdy, R. C., **A.**, 233, 259.
Pyle, G. C., **A.**, 146.

Rand, C. C., **A.**, 162.
Rau, J., **A.**, 277.
Rauter, G., **A.**, 15.
Rayleigh, Lord, **A.**, 180.
Rayton, W. B., **A.**, 249.
Reath, F. F., **A.**, 7.
Rees, W. J., **P.**, 8, 9, 21, 23, 27, 31, 49, 51, 55 ; **T.**, 116, 121, 162, 216, 221, 248, 249.
Reglade, A., **A.**, 205.
Regnault, **T.**, 239.
Reid, W. F., **P.**, 32.
Reynolds, A., **A.**, 63.
Reynolds & Branson, **T.**, 253.
Rhodin, J. G. A., **A.**, 186.
Richards, E. J. W., **A.**, 137.
Rideal, S., **P.**, 33.
Ries, H., **A.**, 56, 57.
Riley, L. J., **A.**, 141.
Ripper, W., **P.**, 22 ; **T.**, 134, 141.
Roberts, H. S., **A.**, 186, 271.
Roberts, O., **T.**, 52.
Robinson, W., **P.**, 15.
Robinson, W. O., **A.**, 71.
Rochow, W. F., **A.**, 257.
Rockwood Silica Co., **T.**, 76, 78.

Roirant, E., **A.**, 77, 193.
Rosenhain, W., **P.**, 24; **T.**, 93; **A.**, 127.
Ross, D. W., **A.**, 61; **T.**, 219; **A.**, 258.
Rossiter, E. C., **A.**, 219.
Royster, P. H., **A.**, 37.
Ryland, H. S., **A.**, 45, 46.

Scheringa, K., **A.**, 234.
Schies, J., **A.**, 274.
Schnurpfeil, H., **A.**, 166, 221.
Scholes, S. R., **A.**, 160.
Schone, E., **A.**, 113.
Schott, F., **T.**, 53, 63, 222, 239, 241, 253, 261, 263, 264, 266; **A.**, 175.
Scott, A., **T.**, 116, 120, 121.
Scott, J., **A.**, 110.
Scullin, M. J., **A.**, 243.
Searle, A. B., **P.**, 13; **T.**, 93.
Seaward, G. A., **P.**, 15.
Selvig, W. A., **A.**, 72.
Sendliger Opt. Works, **A.**, 27.
Shackleton, W., **A.**, 253.
Shane, W., **A.**, 137.
Sharp, W., **A.**, 52.
Shaw, J. B., **A.**, 28.
Shaw, S., **P.**, 21.
Shawbruner, Ltd., **A.**, 146.
Sheard, C., **A.**, 253.
Shenstone, W. A., **A.**, 44.
Shepherd, E. S., **A.**, 103.
Shiver, H. E., **A.**, 71.
Shoaff, P. S., **A.**, 161.
Siedentopf, H., **A.**, 30, 33.
Siemens & Halske, **A.**, 49.
Silverman, A., **A.**, 50.
Simon-Carves, Ltd., **A.**, 134.
Simplex Eng. Co., **T.**, 180.
Simpson, G., **P.**, 15, 54.
Slocombe, F. E., **A.**, 151, 156.
Smith, A. W., **A.**, 253.
Smith, G. O., **T.**, 72.
Smith, J. C., **A.**, 274.
Smith, T., **A.**, 46, 109.
Smith, T. L. Co., **T.**, 172.
Smith, T. T., **A.**, 250.
Smither, F. W., **T.**, 129.
Soc. Chem. Ind., **P.**, 32; **A.**, 92; **T.**, 136, 249, 250, 254.
Solon, M. L., **A.**, 243.
Sorey, T. L., **A.**, 17.
Sosman, R. B., **T.**, 216.
Southall, J., **A.**, 8.
Sparks, T. M., **P.**, 22.
Spencer Lens Co., **A.**, 100; **T.**, 192.
Spinasse, A. E., **A.**, 148.
Splinterless Anti-Mist Glass Synd., **A.**, 16.
Splitgerber, **A.**, 221.
"Sprechsaal," **A.**, 9, 10, 12, 16, 165, 226, 227.
Springer, L., **A.**, 220.
Spurrier, H., **A.**, 58, 117.
Stansfield, E., **A.**, 52.
Stephens, A., **P.**, 10.
Stevens-Adamson Co., **T.**, 171.
Stevenson, A., **P.**, 24, 33.
Stewart, F. W., **A.**, 281.
Stewart, J., **A.**, 136.
Stone, R. W., **T.**, 72.
Stott, V., **P.**, 1, 33, 47; **T.**, 93.
Stover, E. C., **A.**, 57.
Strehl, K., **A.**, 48.
Stuhlmann, O., **A.**, 248.
Swann, F., **P.**, 21.
Sweeting, F., **P.**, 2, 21, 55; **T.**, 27.
Sweeting, G. S., **T.**, 78.
Swinton, A. A. C., **A.**, 102.
Sykes & Sugden, **A.**, 211.

Tanner, W. S., **A.**, 155.
Tavern Rock Silica Co., **T.**, 72.
Taylor, Miss A. B., **T.**, 93.
Taylor, A. H., **A.**, 50.
Taylor, W., **A.**, 85, 89, 217.
Teetor, P., **A.**, 230.
Thackray, C. F., **T.**, 267, 268.
Thatcher Manftg. Co., **T.**, 200.
Thiene, H., **A.**, 244.
Thomas, C. W., Lt.-Col., **P.**, 10, 21, 23.
Thomson, J. J., **A.**, 102.
Thornton, W. M., **A.**, 234.
Tillotson, E. W., **P.**, 49; **A.**, 223.
Tilstone, A., **A.**, 199.
Tilstone, T., **A.**, 199.
Tippetts, P. W. B., **P.**, 22; **T.**, 133.
Togue, G. O., **A.**, 144.
Tokyo Phys. Soc., **A.**, 28.
Tomson, H., **A.**, 212.
"Trans. Optical Soc.", **A.**, 25.
Travers, M. W., **P.**, 8, 9, 21, 24, 27, 31, 32, 48, 51, 54; **T.**, 70, 194, 199, 219, 221, 253, 267; **A.**, 21.
Treischel, C., **A.**, 188.
Triplex Safety Glass Co., **A.**, 157.
Trotter, A. P., **P.**, 22.
Trouton, T., **A.**, 94.
Turner, W. E. S., **P.**, 1, 4, 8, 9, 10, 11, 21, 23, 27, 31, 33, 49, 51, 53–57; **T.**, 37, 50, 52, 125, 129, 132, 135, 138, 141, 147, 166, 222, 228, 238, 254, 258–260, 266, 271, 275, 278, 281; **A.**, 20, 23.
Turner, Mrs. W. E. S., **P.**, 23, 53, 56.
Turner's Glass Co., **P.**, 30.
Turrentine, J. W., **A.**, 161.
Tweeddale, F., **A.**, 209.
Twigg, W. R., **A.**, 194, 201.
Twyman, F., **A.**, 23; **T.**, 61, 237.
Tyrer, T., **P.**, 15.

United Glass Manftrs., **T.**, 183.
U.S. Silica Co., **T.**, 73.

Vail, J. G., **A.**, 237.
Vesely, von V., **T.**, 48.
Villard, **A.**, 24.
Vortmann, G., **A.**, 73.

Waddington & Sons, **P.**, 30 ; **T.**, 136.
Wade, H., **A.**, 209.
Wadsworth, F. L. O., **A.**, 274.
Walford, P., **T.**, 133.
Walker, P. H., **A.**, 24.
Walker, S. S., **A.**, 271.
Wallace, R. C., **A.**, 238.
Warren, W. W., **P.**, 21.
Washburn, E. W., **A.**, 13.
Washington, H. S., **A.**, 53.
Watts, A. S., **A.**, 190.
Webb, D., **P.**, 2, 8 ; **T.**, 23, 25.
Webb, D., Jnr., **P.**, 21, 23, 24.
Wecht, **A.**, 279.
Wedron Silica Co., **T.**, 72, 73.
Weimarn, von, **T.**, 282 ff.
Welsbach Co., **A.**, 49.
Wernicke & Wildschrey, **A.**, 60.
Wertheim, A., 111.
Westlake European Machine Co., **A.**, 79, 80, 81, 82 ; **T.**, 187.
West Riding C.C., **T.**, 134.
Wheeler, H. A., **A.**, 59.
White, A. E., **A.**, 80, 81.
White, W. P., **A.**, 35, 103.
Whitwell, A., **A.**, 45.
Wichers, E., **A.**, 207.
Wien, **T.**, 201.
Wilkinson, J., **P.**, 13 ; **T.**, 92.
Williams, A. C., **T.**, 69.
Williams, A. E., **A.**, 241.
Williams, W. S., **A.**, 162.
Williams-Thomas, H. S., **P.**, 21.
Williams-Thomas, J. S., **P.**, 13.
Wilsey, R. B., **A.**, 251.
Wilson, A. W. G., **A.**, 160.
Wilson, G. V., **T.**, 211, 219, 221, 256.
Wilson, T. G., **T.**, 135.
Wilzin, A., **A.**, 74, 76.
Winkelmann, **A.**, 175 ; **T.**, 222, 239, 261, 263, 264, 266.
Winkler, L. W., **A.**, 202, 203.
Withey, W. H., **A.**, 94.
Wood, R. D., **T.**, 173.
Wood, W. F. J., **P.**, 1, 8, 10, 13, 15, 20, 21, 22, 23, 31, 49, 53–55 ; **T.**, 50, 161.
Wood Bros. Glass Co., **T.**, 214.
Woodhead, S. A., **A.**, 3.
Woodworth, C. W., **A.**, 249.
Wragg, W., **A.**, 133.
Wright, E. N., **A.**, 135.
Wright, F. E., **A.**, 103, 104, 235.
Wynne, W. P., **T.**, 134.

Yensen, T. D., **A.**, 123.
Yorkshire Flint Glass Manftrs. Assn., **T.**, 135.
Yorkshire Glass Bottle Manftrs. Assn., **T.**, 135.
Young, A. R., **P.**, 1.

Zehnder, L., **A.**, 111, 112.
Zeiss, C., **A.**, 111, 217.
Zies, E. G., **A.**, 15, 68.
Zimmer, W. H., **A.**, 166.
Zschimmer, E., **A.**, 20, 97, 100 ; **T.**, 55, 61.
Zsigmondy, R., **A.**, 30, 33, 165.

INDEX OF SUBJECTS

Aberration, Spherical, in Lens, **A.**, 110.
Absorption in Tinted Glasses, Measurement of, **A.**, 35.
  of Light in Isotropic Bodies, **A.**, 34.
  of Ultra-violet and Infra-red Radiations by Glasses, **A.**, 253.
  Pipettes, **A.**, 41.
Accounts for Year 1918, **P.**, 17–20.
Acid Glass, Behaviour of, in a Tank Furnace, **A.**, 223.
Adsorption of Metals from Drinking Water by Glasses, **A.**, 234.
Aerial Photography, Design of Lenses for, **A.**, 250.
Aeronautical Sighting and Range Finding Apparatus, **A.**, 48.
Aeroplane Spars, Optical Determination of Stresses in, **A.**, 49.
Air, in Plastic Clay, Determination of, **A.**, 117.
  Preheating of, **A.**, 133.
Åkermanite, **A.**, 241.
Albite, Specific Heat of, **A.**, 36, 54.
Albolene, **T.**, 119.
Alsace Potash Deposits, **A.**, 5.
Alumina, Expansion of, **P.**, 206.
  Preparation of, **A.**, 93, 94.
Aluminium Hydroxide, Solubility of, **A.**, 205.
Aluminium, Separation from Barium and Calcium in Glass, **A.**, 70.
America, North, Glass Industry of, **T.**, 166.
American Clays, Occurrence and Development of, **A.**, 57.
American Excursion, **P.**, 27, 51.
American Members, Subscription of, **P.**, 53.
American Treasurer, Appointment of, **P.**, 53.
Ammonia Distillation, Scrubber for, **A.**, 108.
Analysis of Glass, Methods of (specially for Boric Oxide, and Arsenic Oxides), **A.**, 68.
Andesine, Specific Heat of, **A.**, 36.
Annealing, **T.**, 179, 180; **A.**, 22, 23, 28.
  Lehrs, Glass, **A.**, 192.
  Temperatures of Magnesia-Soda Glasses, **T.**, 278.
  Temperatures of Lime-Soda Glass, **T.**, 125.
Anorthite, **A.**, 35, 36, 37, 54.
Antimony, Separation of Lead from, **A.**, 73.
Antimony Oxide, as Decolouriser, **A.**, 16, 167.
  as Opacifier in Cast-iron Enamels, **A.**, 29.
Arsenic, Condition of, and its Rôle in Glass, **A.**, 15.
  Acid, Gravimetric Determination of, **A.**, 203.
  as Decolouriser, **A.**, 16, 167.
  Oxides in Glass, Determination of, **A.**, 68.
Aspirators, Standardisation of, **P.**, 41.
Astigmatism, Interchangeability of Planes of Stop and Object, **A.**, 47.
  of Lenses, **A.**, 249.
Athermancy of Glass, **A.**, 170.
Atmosphere, Upper, Simple Apparatus for Estimating Oxygen Content of, **A.**, 106.
Auckland Clays, Technical Analysis of, **A.**, 205.
Augite, **A.**, 12.
Automatic Bottle Conveyors, **T.**, 179.
  Electric Bulb-making Machine, **A.**, 79–82.
  Flowing Device for Feeding Molten Glass, **A.**, 154.
  Glass Bottle Machines, **A.**, 74.
  Glass Gathering, **A.**, 76, 78.
  Production from Semi-automatic Bottle Machine, **T.**, 187.

Babinet Compensator, **A.**, 111
Baddeleyite, **A.**, 124.

Balance Sheet for Year 1918, **P.**, 19.
Ball-clay, Expansion of, **P.**, 210.
Barium Carbonate in Glass Manufacture, **A**, 9.
  and Calcium in Glass, Separation of Aluminium from, **A.**, 71.
  and Lead, Occurring Together in Glass, Determination of, **A.**, 70.
  Glasses, Experiments on, **A.**, 22.
Base Clay, **T.**, 7, 12, 13.
Batch Mixing, in America, **T.**, 170.
  Stones, **A.**, 13, 14.
Beakers, Standardisation of, **P.**, 34; **A.**, 245, 246.
Beer's Law, **A.**, 33.
Bibliography of Art of Glass, **A.**, 243.
Bind Clay, **T.**, 7, 11, 12, 13.
Binoculars, New Construction for Bodies of, **A.**, 48.
Blocks, Tank, **T.**, 4, 8.
Blowing Large Bottles, Carboys, etc., **A.**, 277.
Blowing Moulds, Glass, **A.**, 149.
Blowpipe Burners, **A.**, 178.
Blue Glass, **A.**, 34.
Boiling Points of Solutions, Determination of, **A.**, 107.
Borate Glasses, Analysis of, **A.**, 71.
  Some Chemical Characters of, **A.**, 231.
Boric Acid–Silica Mixtures, Thermal Study of, **A.**, 230.
Boric Oxide in Glass, Determination of, **A.**, 68.
Boron in Glazes, Chemical Rôle of, **A.**, 233.
Bottle Conveyors, Automatic, **T.**, 179.
  Factory, Costing System for, **T.**, 27.
Bottle Glass, Lack of Resisting Power, **A.**, 11.
  Machinery for, Manufacture of, **A.**, 146, 147.
Bottle-glass and Glass Bottles, Manufacture, **T.**, 37.
  Standardisation Committee, **P.**, 31.
Bottle Machines, **A.**, 144, 147, 209, 211.
  Automatic, **A.**, 74.
  Feeding Device for, **A.**, 150, 157.
  Semi-automatic, **A.**, 78.
Bottle Stoppers, **A.**, 90, 209, 212.
Bottles, Faulty, **A.**, 10.
  Hand-made, **T.**, 181.
  Large, Blowing, **A.**, 277.
  Machine-made, **T.**, 182.
  Reagent, Standardisation of, **A.**, 247, 248.
Boxes for Packing Electric Lamps, **A.**, 90.
Boy, Mechanical, New Form of, **A.**, 279.
Brazilite, **A.**, 124.
Bricks, Part II of Study of Silica Products, **A.**, 121.
Bricks, Refractory, **A.**, 60, 185, 188.
  Silica and Other Refractory, made from Non-plastic Material, **A.**, 120.
  Silica, Specification for, **T.**, 6.
  Zirconia, **A.**, 124, 131.
Brookes Flow Feed, **T.**, 188.
Bulb (Electric) Automatic Machines, **A.**, 79, 80, 81, 82.
Bulb-glass, Cutting Machine, **A.**, 215.
Bulbs, Electric Light, Manufacture of, in America, **T.**, 189.
Burettes, Calibrating, **T.**, 34; **A.**, 22.
  Improved Automatic, **A.**, 43.
  Simple Weighing, **A.**, 177.
  Standardisation of, **P.**, 44.
Burners, Atmospheric Gas, **A.**, 134.
  Blowpipe, **A.**, 178.
  Maxon-Premix, **T.**, 178.
Bye-Laws, for Branches of the Society Abroad, **P.**, 6.
By-product Recovery Plant, **T.**, 173.

Calcium, Ferrite and Aluminate, Mixed Crystals of, **A.**, 38.
  and Potassium, Double Salts of, in Cement Mill Flue Dust, **A.**, 219.
  and Zinc, Estimation of, in Presence of Lead, **A.**, 204.
  Gravimetric Determination of, **A.**, 202.
  Separation from Magnesium, **A.**, 202.
Cane and Tubing, Glass, Drawing, **A.**, 150.
Carbonisation of Lignite, **A.**, 52.
Carborundum, **A.**, 128.
  Expansion of, **P.**, 212.
Carboys, Blowing, **A.**, 277.
Casting of Pots, Processes, **T.**, 84, 85, 87.
Cement, in Refractory Composition, **A.**, 127.
  Mill Flue Dust, **A.**, 219.
  Plants, (Potash) Recovery at, **A.**, 160.
  Silica, Specification for, **T.**, 6.
"Chair," **T.**, 182, 198.
Chapin's Method of Determining Boric Oxide, **A.**, 69.
Chapman Agitator, **T.**, 153, 154, 161, 163, 164, 173.
Chemical Glassware, Further Investigations on, **T.**, 129.
  Suggestion for Standardisation of, **A.**, 244.

Chemical and Scientific Glassware in America, **T.**, 191.
Chemical Reactions of Interest to Plate Glass Chemist, **A.**, 224.
China Clay, **A.**, 128 ; **T.**, 95 *ff*.
Chatelier, Le, Pyrometer, **A.**, 141.
Chemistry of the Silicates, Researches in, **A.**, 234.
Chlorine, Volatilisation of Iron from Optical Glass Pots by, **A.**, 186.
Chowning Regulator, **T.**, 174, 199.
Chromium, in Glass, **A.**, 34.
Clay, Burnt, Mechanical Strength of, **A.**, 118.
  Deflocculation and Electrolytic Collection of, **T.**, 79.
  Determination of Air in Plastic, **A.**, 117.
  Expansion of, **P.**, 208 *ff*.
  Firebrick at Furnace Temperature, Porosity and Volume Changes of, **A.**, 55.
  Goods, Moulding of, **A.**, 58, 59.
  and Grog, Mixing of, **T.**, 82.
  Sagger, and Mixtures, Notes on, **A.**, 117.
Clays, American, Occurrence and Development of, **A.**, 57.
  Auckland, Technical Analysis of, **A.**, 205.
  Calculation of Rational Analysis, of, **A.**, 53.
  Pugged, Nature of Air Content, **A.**, 58.
  Raw, Specification for, **T.**, 7, 11.
  Raw, Tensile Strength of, **A.**, 56.
  Refractory, Heat-conductivity of, **A.**, 59.
  X-ray Examination of, **T.**, 112.
Clinker, Removing from Furnaces, **A.**, 135.
Clino-enstatite, **A.**, 239.
Coal, Yellow Glass Produced by, **A.**, 220.
Cobalt in Glass, **A.**, 15, 16, 32, 34, 167.
Coefficient of Expansion, **T.**, 238.
Coefficients of Resistance to Tension and Pressure, **A.**, 176.
Coke, for Analysis, Precaution in Grinding, **A.**, 206.
  Determination of Moisture, **A.**, 72.
Coke Ovens, **A.**, 134, 198.
  Heat Regulator for, **A.**, 199.
  Nozzles for, **A.**, 64.
  Regenerative, **A.**, 65.
Colloidal Glasses, **A.**, 33.
Coloration Method of Decoration, **A.**, 44.
Colorimetric Determination of, Lead Dioxide in Litharge, **A.**, 271.
Coloured Glass in America, **T.**, 197.
Colouring Agents, **A.**, 33, 34.
Colours in Metal Glasses and in Metallic Films, **A.**, 31.
Colour Technology, the Physical Basis of, **A.**, 33.
Compressibility of Solids, **A.**, 26.
Compression of Glass and Quartz, Resistance to, **A.**, 27.
Condensation of Water Vapour on Glass Surfaces, Two Modes of, **A.**, 94.
Condenser, New Reflux, **A.**, 41.
Conductivity, Electrical, of Soda-lime–Silicate Glasses, **A.**, 101.
  Thermal, of Some Solid Insulators, **A.**, 234.
Control, Pyrometric, **T.**, 181.
Conveyors, Bottle, Automatic, **T.**, 179.
Cooling Devices, **T.**, 176 ; **A.**, 139.
Co-operation, Appeal for Continued, **P.**, 50.
Copper Aventurine Glass, Theory of Making, **A.**, 167.
  on Glass, Method for Depositing, **A.**, 108.
  Ruby Glass, **A.**, 32.
"Cords," Causes of, **A.**, 20, 21.
Corrosive Action of Flue Dusts on Refractories, **A.**, 115, 118.
Corundum, Formation of, **T.**, 219.
Costing System for a Glass Bottle Factory, **T.**, 27.
Costs, Manufacturing, in the Glass Industry, **T.**, 14.
Covered Pots, Casting of, **T.**, 87.
Cox Machine, **T.**, 186.
Creeping, Preventing Salts from, **A.**, 71.
Cristobalite, **A.**, 239.
  and Tridymite, **T.**, 116, 218.
  in Porcelain, **A.**, 123.
  Refractive Index of, **A.**, 15.
  Specific Heat of, **A.**, 35, 36.
Crova Method, **A.**, 252.
Crown Drops, **A.**, 13, 14.
Crowns of Glass Furnaces, Deposits on, **A.**, 166.
Cryolite as Flux or Opacifier, **A.**, 29.
  Manufacture of, from Sodium Bisulphate, Silica and Fluorspar, **A.**, 8.
Cullet, Grinding of, **A.**, 21.
  Water, **T.**, 98.
Cutter, Glass, **A.**, 42, 243.
Cutting (Glass) or Dividing Machine, **A.**, 157.
Cutting Machine, Glass Bulb, **A.**, 215.
Cylinders, Glass, Machinery for Drawing, **A.**, 148.
  Standardisation of, **A.**, 247.

Dawson Producer, **T.**, 152.
Day Tanks in America, **T.**, 178.

Decolouriser, **A.**, 16, 166.
Decorative Coatings on Glass, Metallic, **A.**, 44.
Deflocculation and Electrolytic Collection of Clay, **T.**, 79.
Degrees in Glass Technology, Draft Ordinances for, **T.**, 141.
Delegacy for Glass Research, Third Annual Report, **T.**, 132.
Delivering Glass, Apparatus for, **A.**, 274.
Dept. of Glass Technology, **P.**, 21; **T.**, 126.
Dept. of Scient. and Industrial Research, **T.**, 93.
Deposits on Crown of Glass Furnaces, **A.**, 166.
  on Glass Surfaces in Instruments, **A.**, 179.
Desiccators, Standardisation of, **P.**, 41.
Detection of Strain in Glass, **T.**, 256, 258.
Devitrification of Glass, **A.**, 172, 223, 229.
  Stones, **A.**, 13–15.
"Dew," Formation of, **T.**, 59.
Diathermancy of Glass, **A.**, 168.
Didymium Glass, **A.**, 34.
Dilatometric Method, **T.**, 239.
"Dimming" Test, **T.**, 56, 61, 63–69.
Dinner, First Annual, **P.**, 22, 23.
Diopside, **A.**, 239–241.
  Specific Heat of, **A.**, 36.
Dishes, Evaporating, etc., Standardisation of, **A.**, 247.
Distillation, Fractional, Limits of Separation, **A.**, 42.
Distilling Tube, New Form, **A.**, 178.
Dividing or Glass Cutting Machine, **A.**, 157.
Dixon Furnaces, **T.**, 178.
Dog House, **T.**, 176.
Doublets, Cemented, Charts for Assisting Selection of Suitable Glasses for, **A.**, 46.
Drawing Glass Cane and Tubing, **A.**, 150.
  Glass Cylinders, Machinery for, **A.**, 148, 275.
  Glass Tubing, **A.**, 83, 280.
"Drilled" Pots, **T.**, 94, 108.
Drying, Humidity System of, **A.**, 262.
Drying Sand, **A.**, 159.
Drying Towers, Standardisation of, **P.**, 40.
Duff Producer, **T.**, 152.
Dumas' Theory of Glass, **A.**, 12.
Durability of Bottle Glass, Tests for, **T.**, 40.
Dust, Flue, Effect on Refractories, **A.**, 115, 118.

Edison Lamp, **A.**, 171.
Education and Technical Training, Report of Committee on, **T.**, 140.
Eikonal, **A.**, 110.
Elasticity, Young's Modulus of, **A.**, 177; **T.**, 260.
Electric, Bulb-making Machines, Automatic, **A.**, 79–82.
  Furnaces, **A.**, 139, 194.
  Incandescent Lamps, Use of Inert Gases in, **A.**, 49.
  Lamps, Boxes for Packing, **A.**, 90.
  Light Bulbs, Manufacture of, in America, **T.**, 189.
Electrolytic Collection of Clay, **T.**, 79.
Electrometric Titration, **A.**, 271.
Emerald-green Glass, **A.**, 227.
Enamel, Properties of Satisfactory, **A.**, 171.
Erlenmeyer Flasks, **A.**, 245, 246.
Expansion, Coefficient of, **T.**, 238.
  Reversible, of Refractory Materials, **T.**, 201.

Failure of Lead-glass Pots, Causes of, **A.**, 115.
"Favas," **A.**, 124.
Federal Council for Advancement of Chemistry, **P.**, 17.
Feeding Devices, **T.**, 187, 188; **A.**, 150, 153, 154, 274–276.
Felspar, Potassium, **A.**, 40.
Fery's Pyrometer, **A.**, 140.
Filming of Glass, **T.**, 52; **A.**, 25, 46, 94.
Filter, Compensating, in Spectroscopy, **A.**, 251.
Filters, Light, Optical Properties of, **A.**, 250.
Firebrick, Clay, Porosity and Volume Changes at Furnace Temperature, **A.**, 55.
Firebricks, Corrosive Action of Flue Dust on, **A.**, 115, 118.
Fireclay, Expansion of, **P.**, 208.
  Grading, **A.**, 114.
Flasks, Standardisation of, **P.**, 34; **A.**, 245–247.
Flint Glass, White, **T.**, 127.
Flowing Device, Automatic, for Feeding Molten Glass, **A.**, 154.
Fluids on Glass, Spreading of, **A.**, 234.
Flue Dusts, Corrosive Action on Refractories, **A.**, 115, 118.
Fluorspar, Analysis of, **A.**, 204.
"Fluxes," **A.**, 100.
Formation of Glass, Notes on, **T.**, 282.
Forsterite, **A.**, 239, 240.
Frink Regulator, **T.**, 173.

- Fry Ovenware, **T.**, 191.
- Fuel Economisers, **A.**, 52.
  - Problems in Utilisation of, **A.**, 182.
- Funnels, Standardisation of, **P.**, 39.
- Furnace Charges, **T.**, 18.
  - Doors, Fittings for, **A.**, 133.
  - Gas-fired pot, Experiments with, **T.**, 70.
  - Linings, **A.**, 62, 63.
- Furnaces, Deposits on Crowns of, **A.**, 166.
  - Electric, **A.**, 139, 194.
  - Gaseous Fuel, **A.**, 194.
  - Glass, **A.**, 191, 192, 193, 198.
  - Glass-melting, in America, **T.**, 172.
  - Indicator for, **A.**, 200.
  - Industrial, Selection of Refractories for, **A.**, 257.
  - Recuperative, a New Type of, **A.**, 127.
  - Regenerative Coke and Muffle, **A.**, 134.
  - Regenerative Liquid Fuel, **A.**, 131.
  - Regenerative, Reversing Valves for, **A.**, 137, 201.
  - Re-heating, **A.**, 137, 139.
  - Removing Clinker from, **A.**, 135.
  - Tank, Manufacture of Table Ware in, **T.**, 242.
  - Tank, Note on Preliminary Firing of, **T.**, 147.
  - and Gas Producer, Glassworks', Recent Improvements in, **T.**, 148.
  - for Powdered Fuel, **A.**, 137.

- Gall, Bubbles, **A.**, 10.
- Gas, Natural, Analysis of, **A.**, 208.
- Gas Burners, Atmospheric, **A.**, 134.
- Gaseous-fuel Furnaces, **A.**, 194.
- Gases, Apparatus for, Continuous Testing of, **A.**, 42.
- Gas-fired Pot Furnace, Some Experiments with, **T.**, 70.
- Gas-mantle Lamps, Influence of Quality of Gas, etc., on Efficiency, **A.**, 50.
- Gas Producers, **T.**, 148 ; **A.**, 66, 135, 136, 173, 256.
- Gathering Glass, **A.**, 76, 78, 273.
- Gaussian Equations, **A.**, 110.
- Gehlenite, **A.**, 37.
- "Gel," **T.**, 83, 84.
- Geometrical Optics, Symbols and Designations for, **A.**, 250.
- German Glassworks in March–April, 1919, **T.**, 144.
- Glass, Adsorption of Metals from Drinking Water by, **A.**, 234.
- Glass, Analysis, Methods of, with Special Reference to Boric Oxide, and Arsenic Oxides, **A.**, 68.
  - Apparatus for Delivering, **A.**, 274.
  - Apparatus for Drawing, **A.**, 274, 280.
  - Barium, Experiments on, **A.**, 222.
  - Bibliography of the Art of, **A.**, 243.
  - -blowing Moulds, **A.**, 149.
  - Bulb Cutting Machine, **A.**, 215.
  - Chemical Constitution and Properties, **A.**, 12.
  - Coloration by Natural Solar and Other Radiations, **A.**, 30.
  - Copper Aventurine, **A.**, 167.
  - Cutter, **A.**, 42, 243.
  - Cylinders, Machinery for Drawing, **A.**, 148.
  - Detection of Strain in, **T.**, 256, 258.
  - Devitrification of, **A.**, 172, 223, 239.
  - Difference between Burning Off and Skimming Off, **A.**, 10.
  - Emerald-green, **A.**, 227.
  - Flaws, **A.**, 110.
  - for Lamp Workers, **T.**, 249, 266.
  - for Table Working, **T.**, 253.
  - Formation of, Notes on, **T.**, 282.
  - Gathering, Machinery for, **A.**, 273.
  - Gold Ruby, **A.**, 164.
  - Hardness of, **A.**, 175.
  - House Pots, Preparation of Raw Materials for and Manufacture of, **T.**, 78.
  - Industry, Manufacturing Costs in, **T.**, 14.
  - Industry of North America, **T.**, 166.
  - -making machinery, **A.**, 77, 211, 274.
  - -making Processes, **A.**, 20.
  - Manufacture, Feeding Devices in, **T.**, 187 ; **A.**, 150, 153, 154, 274–276.
  - Method for Depositing Copper on, **A.**, 108.
  - of Low Resistivity, **A.**, 29.
  - Opal and Green, **A.**, 226.
  - Opalescent Red, **A.**, 165.
  - Pressed, Machinery for Production of, **A.**, 278.
  - Refractories, Provisional Specifications for, **T.**, 3.
  - Research Delegacy, Third Annual Report, **T.**, 132.
  - Ruby, **A.**, 164, 241.
  - Sands in U.S.A., Exploitation of, **T.**, 172.

Glass-shaping Machine, **A.**, 141.
  Sheet, **A.**, 213.
  Spreading of Fluids on, **A.**, 234.
  Strengthened, **A.**, 16.
  Vessels, Permeability of, **A.**, 25.
  Viscosity of, Variation of with Composition, **T.**, 43–49.
  Welding, Notes on, **A.**, 168.
  Yellow, **A.**, 34.
    Produced by coal, **A.**, 220.
  Yellow Tank, **A.**, 9.
Glasses, Annealing Temperatures of Magnesia-Soda, **T.**, 125, 278.
  Borate, Chemical Character of, **A.**, 231.
  Electrical Conductivity of Soda-lime–Silicate, **A.**, 101.
  Heat Expansion of Soda-lime, **T.**, 238.
  Lime-soda, Durability of, **T.**, 228.
  Properties of, **T.**, 22.
  Young's Modulus for, **T.**, 260.
Glassware, Chemical and Scientific, **T.**, 191 ; **A.**, 21, 24.
  Chemical, Committee for Standardisation of, **P.**, 27, 31.
    Further Investigations on, **T.**, 129.
    Industry, Scientific, Some Aspects of, **A.**, 23.
    Standardisation of, **A.**, 244.
Glassworks, German, in March-April, 1919, **T.**, 144.
Glazes, Chemical Rôle of Boron in, **A.**, 233.
" Glory holes," **A.**, 183.
Goerz, C. P., Testing Materials at Optical Institute of, **A.**, 48.
Gold Ruby Glass, **A.**, 30, 164.
Grading Fireclay, **A.**, 114.
Graham Machine, **T.**, 183.
Green Glass, **A.**, 34.
Green (Emerald) Glass, **A.**, 227.
Griffin Beakers, **A.**, 245, 246.
Grinding and Polishing Machinery, **A.**, 85, 88, 89, 151, 155, 156, 215, 217, 281.
Grog, Preparation of, **T.**, 81.
  Grinding of, **T.**, 81.
  in Ceramic Bodies, **A.**, 59.
  Mixing of Clay and, **T.**, 82.
  Size of, **T.**, 82.
  Specification for, **T.**, 14.
Ground Glass Joints, Use of Standard Dies in Making, **A.**, 105.

Hamilton's " Characteristic Function," **A.**, 111.
Hardness of Glass, **A.**, 175, 176.
Hartford-Fairmont Machine, **T.**, 184, 188.
Headlight Beam, Mathematical Study of, **A.**, 255.
Heat-balance on a Producer-gas-fired Chamber Kiln, **A.**, 66.
  Insulation and Lagging Materials, **A.**, 64.
Hermansen Furnace, **T.**, 155, 158.
"Herring Bone," Appearance, **A.**, 110.
High Temperature Work on the Silicates, **A.**, 238.
Hilger's Strain Viewer, **A.**, 23.
Holborn-Kurlbaum Pyrometer, **A.**, 141, 252.
Hooke's Law, **A.**, 112.
Howard Feeder, **T.**, 189.
Hughes Producer, **T.**, 153.
Humidity System of Drying, **A.**, 262.
Hydrothermal Formation of Minerals (Silicates), **A.**, 40.

Ideal, Our (Presidential Address), **T.**, 50.
Illuminating Ware in America, **T.**, 197.
Indicator for Furnaces, **A.**, 200.
Infra-red Radiations, Absorption of, by Glasses, **A.**, 253.
Inst. of Chemistry, **P.**, 24.
Instruments, Deposits on Glass Surfaces in, **A.**, 179.
Insulators, Solid, Thermal, Conductivity of Some, **A.**, 234.
Iodoeosin Test, **T.**, 55.
Iron, Determination of, by Electrometric Titration, **A.**, 271.
  in Glass, **A.**, 34.
  in Optical Glass, Determination of, **A.**, 70.
  Volatilisation of, by Chlorine, from Optical Glass Pots, **A.**, 186.

" Jena " Glass, **T.**, 63 ; **A.**, 21, 23, 30, 97, 140.
Joints, Ground Glass, Use of Standard Dies in Making, **A.**, 105.

Kaolin, Expansion of, **P.**, 206.
Kaolinite, **P.**, 211.
Kiln, **A.**, 198.
Kiln-Annealing, **T.**, 180.
  Heat Regulator for, **A.**, 199.
  Muffle, **A.**, 196.
  Producer Gas-fired Chamber, **A.**, 66.
  Tunnel, **A.**, 196.
Kipp's Apparatus, Standardisation of, **P.**, 38.
Kjeldahl Flasks, **A.**, 245, 247.
Kneading and Pugging, Comparative Value of, **A.**, 188.

Laboratory Glassware, Report of Standardisation Committee on, **P.**, 32.
Labour Charges, **T.**, 20.
  Conditions in America, **T.**, 194.
Lagging Materials, Heat Insulation and, **A.**, 64.
Lamp-blown Apparatus, Standardisation of, **P.**, 47.
Lamp Manufacture, **A.**, 255.
Lamps, Electric, Incandescent, Use of Inert Gases in, **A.**, 49.
Lamps, Gas Mantle, Efficiency of, **A.**, 50.
Lampworking, Glass for, **T.**, 249, 266.
  School, Report of Board of Management, **T.**, 137.
  Standardisation Committee, **P.**, 31.
Lead, and Barium Occurring together in Glass, Determination of, **A.**, 70.
  Dioxide in Litharge, Colorimetric Determination of, **A.**, 271.
  Estimation of, as Phosphate, and Separation from Antimony, **A.**, 73.
  Oxide, Volatilisation of, from Lead Silicate Melts, **A.**, 230.
Leblanc Rotary Pump, **T.**, 91.
Lehrs, **A.**, 22, 192.
  Muffle, **A.**, 269.
  Muffle, in America, **T.**, 180.
Lens, Reflected Images in, **A.**, 249.
  Spectacle, Blemishes in, **A.**, 110.
  Systems, **A.**, 45, 109, 250.
Lenses, Astigmatism of, **A.**, 249.
  Chart for finding Number and Size in a Block, **A.**, 45.
  Design of, for Aerial Photography, **A.**, 250.
  Grinding and Polishing, **A.**, 44, 88, 155, 217, 281.
  Spherical Abberration of, **A.**, 110.
Leucite, **A.**, 40.
Libbey-Owens Process, **T.**, 198.
Library Additions, **P.**, 16.
Light Filters, **A.**, 250, 251.
Lighting, Good, Fundamental Principle of, **A.**, 254.
  Street, Developments at Oxford, **A.**, 50.
Lignites, Carbonisation of, **A.**, 52.
Lime, Alumina–Silica System, and its Relation to Blast Furnace Slags and Portland Cement, **A.**, 39.
  Deterioration on Keeping, **A.**, 3.
  for Various Purposes, Valuation of, **A.**, 72.
  Influence on Young's Modulus, **T.**, 260.
Lime, Magnesia–Silica System, **A.**, 240.
  Silica Series of Minerals, **A.**, 103.
  Soda Glasses, Annealing Temperature of, **T.**, 125.
    Durability of, **T.**, 228.
    Heat Expansion of, **T.**, 238.
    Properties of, **T.**, 222.
    Young's Modulus for, **T.**, 260.
Lindo-Gladding Method for Determining Potash, Sources of Error, **A.**, 71.
Linn By-product Recovery System, **T.**, 173.
Lippmann Colour Photographs as Sources of Monochromatic Light, **A.**, 251.
Lubricants, Effects of Treating Glass Surfaces with, **A.**, 253.
Lummer-Brodhun Photometer, **A.**, 141, 252.
Lunge's Oxalic Acid Titration Method for Valuation of Lime, **A.**, 73.
Lynch No-Boy Machine, **T.**, 185.

Machinery, Glass-making. See under *Glass.*
  Grinding and Polishing, **A.**, 85, 88, 89.
Magnesia, Brick, **P.**, 212; **A.**, 259.
  in Glass, **T.**, 46.
  Soda Glasses, **T.**, 275.
    Annealing Temperatures of, **T.**, 278.
  Ware, **A.**, 123.
Magnesite Bricks, **A.**, 131, 259.
Magnesium, Alkalimetric Determination of Small Amounts of, **A.**, 202.
  Separation of, from Calcium, **A.**, 202.
Manganese in Glass, **A.**, 16, 29, 34, 167.
Marking (Permanent) of Glass Vessels, **A.**, 105.
Mathematical Study of a Headlight Beam, **A.**, 255.
Maxon Premix Burner, **T.**, 178.
Measuring Flasks and Cylinders, Standardisation of, **P.**, 47; **A.**, 245–247.
Mechanical Boy, New Form of, **A.**, 279.
Metallic Mirrors, Films and Prisms, Preparation of, by Distillation, **A.**, 248.
Metals, Adsorption of, from Drinking Water by Glass, **A.**, 234.
Methane, **A.**, 51.
$MgSiO_3$, Minerals of the Composition, **A.**, 104.
Microline, **T.**, 119; **A.**, 36.
Microscope Objective, Examination of, **A.**, 48.

Microscopes, Micrometer, **A.**, 47.
  New Illumination for, **A.**, 50.
Microstructure of Porcelain, Effect of Time and Temperature on, **A.**, 190.
Milkiness in Optical Glass, **A.**, 18, 19.
Miller (Edward) Machine, **T.**, 185, 188, 197.
Miller (W. J.) Machine, **T.**, 185, 187, 189, 197.
Mirrless-Leblanc Multijector Air Pump, **T.**, 91.
Mirrors, Films and Prisms, Metallic, Preparation of, by Distillation, **A.**, 248.
Mixing of Batch, in America, **T.**, 170.
Mixing of Clay and Grog, **T.**, 82.
Mixing "Slip," **T.**, 82, 83.
"Model" Analysis, **A.**, 53.
Moisture in Coke, Determination of, **A.**, 72.
Monazite, **A.**, 125.
Monochromatic Light, Lippmann Colour Photographs as Sources of, **A.**, 251.
Monticellite, **A.**, 239, 240.
Morgan Producer, **T.**, 153, 173.
Moulds, for Hollow Ware, **A.**, 11.
  Glass Blowing, **A.**, 149.
Muffle, Furnaces, Regenerative, **A.**, 134.
  Kiln, **A.**, 196.
  Lehr, Simplex, **A.**, 267.
  Lehrs, **A.**, 269.
  Lehrs in America, **T.**, 180.

National Physical Laboratory, **P.**, 24.
Natural Gas, Analysis of, **A.**, 208.
Nepheless, **A.**, 253.
Nepheline, Potassium, **A.**, 40.
Nickel Crucibles for Lawrence Smith Fusion, **A.**, 271.
  in Glass, **A.**, 15, 16, 34, 167.
No-Boy Machine, Lynch, **T.**, 185.
North America, Glass Industry of, **T.**, 166.

Obituary: **P.**, 12, 27, 29, 30.
Occlusion of Residual Gas by Glass Walls of Vacuum Tube, **A.**, 102.
Officers for 1919–20, **P.**, 20, 21.
Oil-firing, **A.**, 21.
Oncost Charges, **T.**, 21, 29.
O'Neill Machine, **T.**, 184, 197.
Opal, and Green Glasses, **A.**, 226.
  and Violet Opal Glass, **A.**, 165.
  on Surface of Barium Glass, **A.**, 178.
Opalescence, Produced by Traces of SO_3 and Cl, **A.**, 20.
Opalescent Red Glass, **A.**, 165.
Optical Glass, Determination of Iron in, **A.**, 70.
  Effect of Certain Impurities in Causing Milkiness, **A.**, 17, 18, 19.
  in America, **T.**, 191.
  in Relation to Weathering Properties, Examination of, **T.**, 52.
  Iron in Furnace Atmosphere as a Source of Colour in, **A.**, 13.
  Manufacture of, **A.**, 20, 95, 100, 162, 163.
  Standardisation Committee, **P.**, 31.
  Volatilisation of Iron by Chlorine, from Pots, **A.**, 186.
Optical, Equation, Some Generalised Form of, **A.**, 109.
  Inst. of C. P. Goerz, Testing Materials at, **A.**, 48.
  Instruments (Enclosed), Prevention of Film in, **A.**, 46.
  Stray Light in, **A.**, 47.
  Properties of Light Filters, **A.**, 250.
Optics, Geometrical, Symbols and Designations for, **A.**, 250.
Ovens, Coke, **A.**, 64, 65, 198.
  Heat Regulator for, **A.**, 199.
Owen's A. W. Machine, **T.**, 183.
Owen's Bottle Company, **T.**, 175, 179, 181 ff.
Owen's Machine, German Bottle Batch for, **T.**, 44.
Oxygen, in Air, Simple Apparatus for Estimating, **A.**, 106.
  Sodium Pyrogallate Solution, as Absorbent for, **A.**, 208.

Packing Electric Lamps, Boxes for, **A.**, 90.
Palau and Rhotanium Ware as Substitutes for Platinum, **A.**, 207.
Paste Mould Machine, **A.**, 281.
Pectolite, **A.**, 40.
Peligot's Glass, **A.**, 12.
Periclase, **A.**, 239, 240.
Permeability of Glass, **A.**, 24, 25.
Phosphate Method for Determining Zirconium, **A.**, 272.
Phosphoric Acid, Gravimetric Determination of, **A.**, 203.
Photochemical Theory of Vision and Photography, **A.**, 253.
Photometer Comparison, New Type of, **A.**, 252.
Pipettes, Standardisation of, **P.**, 42.
Planck's Constant, **A.**, 140.
Plasticity and Tensile Strength, Measurement of, **A.**, 57.

- Plate Glass, Chemist, Chemical Reactions of Interest to, **A.**, 224.
  - in America, **T.**, 198.
  - Works, Raw Materials for, **A.**, 10.
- Platinising Pottery, **A.**, 179.
- Polarimeter, New Half Shade, **A.**, 111.
- Polarisation of Light by Reflection from Glass, **A.**, 112.
- Polariscope and its Application to Glass Industry, **T.**, 256.
- Polishing and Grinding, Machinery, **A.**, 85, 88, 89, 151, 155, 156, 215, 217, 281.
- Porcelain, Bodies, Comparative Value of Kneading and Pugging, **A.**, 188.
  - Microstructure of, Effect of Time and Temperature on, **A.**, 190.
  - Mixtures, Vitrification and Solution in, **A.**, 190.
  - Notes on Certain Characteristics of, **A.**, 123.
- Pot-attack, Some Phenomena of, **T.**, 93.
- Pot Furnaces, Experiments with Gas-fired, **T.**, 170.
  - in America, **T.**, 177.
  - Works Problems, Report of Committee on, **T.**, 138.
- Pots, Glass-house, Preparation of Raw Materials for, and Manufacture of, **T.**, 78.
  - Lead Glass, Apparent Causes of Failure of, **A.**, 115.
  - Protection of Vulnerable Areas in, **T.**, 109.
  - Raw Clays and Grog for, **T.**, 11.
- Pot Stones, **A.**, 13, 14.
- Potash, Deposits in Alsace, **A.**, 3.
  - Discovery in Sicily, **A.**, 161.
  - Errors in Lindo-Gladding Method for Determining, **A.**, 71.
  - from Kelp, **A.**, 161.
  - from Lakes in Nebraska, **A.**, 7.
  - Industry in Britain, **A.**, 3, 219.
  - Recovery at Cement Plants, **A.**, 160.
  - Salts in Hungary, **A.**, 7.
  - Value of Soils, Determination of, by Lawrence Smith Method, Using Nickel Crucibles, **A.**, 271.
- Potassium, and Calcium, Double Salts of, in Leaching Cement Mill Flue Dust, **A.**, 219.
  - and Sodium Nitrate, Separation of, **A.**, 160.
  - Carbonate, **A.**, 160.
  - Salts, **A.**, 7.
- Powdered Fuel, Furnaces for Utilising, **A.**, 137.
- Powell's Flint Glass, **A.**, 29.
- Preheating of Air, **A.**, 133.
- Presidential Address, **P.**, 50.
- " Prescription Machine," **T.**, 185.
- Presentations to Mr. Wood and Dr. Turner, **P.**, 53, 55.
- Pressed Glass, Machinery for Production of, **A.**, 278.
- Prism, Field of, **A.**, 45.
- Prisms, Right-angled, Method of Testing, **A.**, 45.
- Producer-gas-fired Chamber Kiln, Heat Balance on, **A.**, 66.
- Producers, American, **T.**, 173.
  - Charging, **A.**, 135.
  - Gas, **A.**, 136.
  - Recent Improvements in, **T.**, 148.
- Pseudo-wollastonite, **A.**, 239, 241.
- Publications Committee Report, **P.**, 24.
- Pugging, **T.**, 82 ; **A.**, 117, 188.
- Pumps, Air, **T.**, 91.
- Purple Glass, **A.**, 34.
- Pyrex Glassware, **T.**, 191.
- Pyrite, **T.**, 75.
- Pyrometric Control, **T.**, 181.
- Pyrometry, Basis and Methods of, **A.**, 140.

- Quartz Glass, **A.**, 24.
- Quartz, **T.**, 124.
  - α- and β-, **P.**, 207, 213, 217.
  - and Cristobalite, **A.**, 123.
  - Specific Heat of, **A.**, 35, 36.

- Radio-tellurium, Fluorescence Produced by, **A.**, 30.
- Radium, Phosphorescence, Caused by β- and γ-Rays, **A.**, 29.
- Range Finder, Possible Disturbance of by Motion of a Ship, **A.**, 180.
- Range Finders, Improvements in, **A.**, 48.
- Range Finding Apparatus, Aeronautical Sighting and, **A.**, 48.
- " Rational Analysis " of Clays, **A.**, 53, 205.
- " Rattler " Test, **A.**, 236.
- Reagent Bottles, Standardisation of, **A.**, 247, 248.
- Receivers, Standardisation of, **A.**, 248.
- Recuperative Furnace, New Type of, **A.**, 127.
  - Stein, **T.**, 155.
- Red (Opalescent) Glass, **A.**, 165.
- Reflection and Transmission Factors, Measurement of, **A.**, 255.
- Refraction, Double, **A.**, 111, 112.
- Refractive Indices of Crystals Found in Glass, **A.**, 15.

- Refractories, **A.**, 184.
  - Corrosive Action of Flue Dusts on, **A.**, 115, 118.
  - Glass, Provisional Specifications for, **T.**, 3.
  - Manufacturers, Co-operation with, **P.**, 10.
  - Research and Specifications Committee, **P.**, 7, 17.
  - Selection of, for Industrial Furnaces, **A.**, 257.
  - Silica, **A.**, 60, 258.
  - Some Light Weight Clay, **A.**, 185.
  - Superior, **A.**, 259.
- Refractoriness of Fire-bricks, Tests of, **A.**, 56.
- Refractory Compositions, **A.**, 127.
- Refractory Materials,
  - Firing of, **A.**, 63.
  - for Glass Works, **A.**, 52.
  - in America, **T.**, 193.
  - Melting Point of, **A.**, 261.
  - Relative Volatilities of, **A.**, 259.
  - Reversible Expansion of, **P.**, 201.
  - Standardisation of Tests for, **T.**, 3; **A.**, 113.
- Refractory Silica Bricks, Composition of, **A.**, 60.
  - Substances for Furnace Linings, **A.**, 63.
  - Ware from Zirconia, **A.**, 61.
- Regeneration Chambers, **A.**, 263.
- Regenerative Coke and Muffle Furnaces, **A.**, 134.
  - Furnaces, Reversing Valves for, **A.**, 137, 201.
  - Liquid Fuel Furnaces, **A.**, 131.
- Regulator, Heat, for Ovens and Kilns, **A.**, 199.
- Regulators, **T.**, 173, 174, 199, 200.
- Re-heating Furnaces, **A.**, 137, 139.
- Report for Year 1918, **P.**, 15.
- Retorts, Standardisation of, **A.**, 248.
- Reverberatory Furnaces, **A.**, 192.
- Reversing Valves for Regenerative Furnaces, **A.**, 137, 201.
- Rhodonite, **A.**, 234.
- Rhotanium and Palau Ware as Substitute for Platinum, **A.**, 207.
- Rod and Tubing, Glass, Manufacture of in America, **T.**, 190.
- Ruby Colour in Glass, Notes on Development of, **A.**, 241.
- Ruby Glass (Gold), Development of Improved, **A.**, 164.
- Rules, Amendment of, **P.**, 20.

- Sagger Clays and Mixtures, Note on, **A.**, 117.
- Salamander, **A.**, 128.
- Sampling Granular and like Materials, **A.**, 141.
- Sand, Drying, **A.**, 159.
  - Separators for, **A.**, 93.
  - Standard, **T.**, 75.
  - Washing, **A.**, 8.
- Sands, Glass, Exploitation of, in U.S.A., **T.**, 72.
- Science and the Glass Industry in America, **T.**, 196.
- Scientific Glassware, **A.**, 21, 23.
  - in America, **T.**, 191.
- Scrubber for Ammonia Distillation, **A.**, 108.
- Selenium, as Colouring Agent, **A.**, 33.
  - as Decoloriser, **A.**, 15, 16, 167.
- Semi-automatic Bottle-making Machine, **A.**, 79, 144.
  - Production from, **T.**, 187.
- Separators for Sand, **A.**, 93.
- Shaping Machines, Glass, **A.**, 141, 244.
- Sheet Glass, Manufacture, **A.**, 213.
  - Strength Tests for Plain and Protective, **A.**, 17.
- "Shop," **T.**, 182, 198.
- Silica, Bricks, **T.**, 6; **A.**, 60, 119, 121.
  - Cement, **T.**, 6.
  - Expansion of, **P.**, 207.
  - "Flour," **T.**, 75.
  - Refractories, **A.**, 60, 258.
  - Solubility of, **A.**, 72.
  - (Vitreous) Optical Properties of, **A.**, 44.
- Silicate of Soda, Commercial, Properties of, **A.**, 237.
- Silicates, (Fusing) Physical Chemistry of, **A.**, 236.
  - High Temperature Work on, **A.**, 238.
  - Researches in Chemistry of, **A.**, 234.
- Sillimanite, Formation of, **T.**, 217, 221.
  - in Porcelain, **A.**, 123, 190.
  - in Pot Stones, **A.**, 14.
  - Refractive Index of, **A.**, 15.
- Silvered Surfaces, Protection of, **A.**, 249.
- Silver in Glass, **A.**, 34.
- Simplex Muffle Lehr, **A.**, 267.
- Slag Control by Means of Slag Viscosity Tables, **A.**, 38.
- Slags, Basic, containing Fluorine, Analysis of, **A.**, 204.
- "Slipping," **T.**, 82, 83.
- Sodium Pyrogallate Solution as Absorbent for Oxygen, **A.**, 208.
- Solubility, of some Salts in Glass, **A.**, 227.
  - of Zinc Oxide in Fused Lead Silicate and Borate, **A.**, 229.
- Solvay's Method for Valuation of Lime, **A.**, 73.
- Specific Heats, Silicate, **A.**, 35.

Specifications for Glass Refractories, Provisional, **T.**, 3; **T.**, 113.
Spectacle Lens, Blemishes, **A.**, 110.
  Reflected Images in, **A.**, 249.
Spectrometry, Photo-electric, by the "Null Method," **A.**, 252.
Spectroscopy, Compensating Filter in, **A.**, 251.
Spencer's Cane Sugar Method for Valuation of Lime, **A.**, 73.
Spherical Aberration in Lens, **A.**, 110.
Spreading of Fluids on Glass, **A.**, 234.
Standard Formula for a Glass for Lamp Workers, **T.**, 249.
"Standard Sand," **T.**, 75.
Standardisation, of Glassware, **P.**, 17, 27, 31, 32; **A.**, 244.
  of Tests for Refractories with Specification, **T.**, 3; **A.**, 113.
Statical Process for Casting Pots, **T.**, 84.
"Steaming" of Glass Surfaces, Prevention of, **A.**, 253.
Stein Recuperative Furnace, **T.**, 155.
Still-head, New, **A.**, 42.
"Stones" in Glass, Identification of, **A.**, 13.
Stopcock for Dropping Liquids, **A.**, 40.
Stopcocks, Device for Removing Plugs from, **A.**, 104.
Stoppers, Bottle, **A.**, 90, 209, 212.
Stourbridge Fireclay, **A.**, 120.
Strain Viewers, **T.**, 256, 258.
Stress-optical Co-efficient, **A.**, 111.
Suction, Automatic Gathering of Glass by, **A.**, 78.
Sulphur in Glass, **A.**, 34.
Surface Devitrification of Glasses under Thermal After-treatment, **A.**, 229.
"Surface Factor" Method of Classifying Clays, **A.**, 114.

Table Ware, Manufacture of, in Tank Furnaces, **T.**, 242.
Table Working, Glass for, **T.**, 253.
Talbot Producer, **T.**, 153.
Talbot Stirrer, **T.**, 160, 161, 164.
Tank Blocks, Specification for, **T.**, 4, 8.
Tank Furnaces, Behaviour of an Acid Glass in, **A.**, 223.
  in America, **T.**, 174.
  Manufacture of Table Ware in, **T.**, 242.
  Preliminary Firing of, **T.**, 147.
Tanks, Day, **T.**, 178.
Taylor and Sullivan's Method for Determining Boric Oxide, **A.**, 69.
Technical Training and Education, Report of Committee on, **T.**, 140.
Temperature, Influence of, on Absorption of Light in Isotropic Bodies, **A.**, 34.
Temperature-viscosity, Relations in Ternary System, Lime, Alumina, Silica, **A.**, 37.
Ternary System, CaO–MgO–SiO_2, **A.**, 239, 240.
Testimonial Fund, **P.**, 53, 55.
Thermal Study of Boric Acid, Silica Mixtures, **A.**, 230.
Thermometer, Lags of, **A.**, 43.
Thorium, Compounds, Preparation of, **A.**, 113.
  Pyrophosphate, **A.**, 49.
  Salts, **A.**, 181.
Transmission and Reflection Factors, Measurement of, **A.**, 255.
Transparency of Glasses to Ultra-violet Light, Variation of, with Composition, **A.**, 100.
Tridymite, **A.**, 239.
  and Cristobalite, relations between, **T.**, 116.
  Bricks, **A.**, 60.
  in Barium Glass, **A.**, 174.
  in "Stones," **A.**, 14, 15.
  Inversion to, **P.**, 208.
  Refractive Index of, **A.**, 15.
Tubing, Drawing, **A.**, 83, 150, 280.
  Manufacture of, in America, **T.**, 190.
Tubular Glass Articles, Machine for Shaping, **A.**, 244.
Tucker Reeves Feeder, **T.**, 188.
Tungstic Oxide, Reduction of, **A.**, 181.
Tunnel Kiln, **A.**, 196.
Twentieth Century Machine, **T.**, 186.

Ultra-microscopic Particles, Magnitude of, **A.**, 30.
Ultra-violet Light, Action on Glass, **A.**, 30.
  Variation of Transparency of Glasses to, **A.**, 100.
Ultra-violet Radiations, Absorption of, by Glasses, **A.**, 253.
Uranium Glass, **A.**, 34.
U.S.A., Exploitation of Glass Sands in, **T.**, 72.

Vacuum Casting Process for Pots **T.**, 85, 87.
Vacuum Tubes, Occlusion of Residual Gas by Glass Walls of, **A.**, 102.
Violet Opal Glass, Batch Mixtures for, **A.**, 166.

Viscosity, Variation of, with Composition of Glass, **T.**, 43–49 ; **A.**, 236.
Vitrification and Solution in Porcelain Mixtures, **A.**, 190.
Volatilisation of Lead Oxide from Lead Silicate Melts, **A.**, 230.
Volatilities (Relative) of Refractory Materials, **A.**, 259.
Volumes, Accurate Determination of, **A.**, 22.

Washing and Stoppering Bottles, **A.**, 212.
Watch Glasses, Standardisation of, **A.**, 247.
"Water Cullet," **T.**, 98.
Water-gas Formation, Theory of, **A.**, 51.
Water Vapour on Glass Surfaces, Condensation of, **A.**, 94.
Weathering Properties, Optical Glass in Relation to, **T.**, 52.
Weber's Formula for Glass, **A.**, 12.
Welding of Glass, Notes on, **A.**, 168.
Westlake Machine, **T.**, 187.
Wherry's Method for Determining Boric Oxide, **A.**, 69.
White Flint Glass, **T.**, 127.
Willemite, **A.**, 234.
Wilson-Producer, **T.**, 152.
Window Glass in America, **T.**, 198.
Winkelmann and Schott's Linear Co-efficients, **A.**, 175.
Wire-glass, **A.**, 171.
Wollastonite, and Pseudo-wollastonite, **A.**, 103, 239–241.
  from Soda and Potash Glasses, **A.**, 12.
Wollastonite, in Crown Glass, **A.**, 174.
  in Plate Glass, **A.**, 173.
  in Spectacle Lens, **A.**, 110.
  in "Stones," **A.**, 15.
  in the Ternary System, Lime–Magnesia–Silica, **A.**, 240.
  Inversion to, **A.**, 103.
  Refractive Index of, **A.**, 15.
  Specific Heat of, **A.**, 35, 36.
Wood Medal and Prize, **P.**, 55.
Wood (R. D.) Producer, **T.**, 153, 173.
Woulfe's Bottles, Standardisation of, **P.**, 41.

X-ray Examination of Clays and Clay Bodies, **T.**, 112.

Yellow Glass, **A.**, 34.
  Produced by Coal, **A.**, 220.
Yellow Tank Glass, **A.**, 9.
Young's Modulus, **A.**, 177.
  Influence of Lime on, for Lime-soda Glasses, **T.**, 260.

Zeolites, **A.**, 40, 54.
Zinc, and Calcium in Presence of Lead, Estimation of, **A.**, 204.
  in Glass, Determination of, **A.**, 70.
  Oxide, Solubility of a Fused Lead Silicate and Borate, **A.**, 229.
Zircon, **A.**, 124.
Zirconia, and its Uses, **A.**, 124, 131.
  Partial Purification of, **A.**, 61.
  Production of Highly Refractory Ware from, **A.**, 61.
Zirconium, Estimation of, **A.**, 205.
  Metallic, **A.**, 126.
Zirkite, **A.**, 124–127.
Zulkowski's Theory of Glass, **A.**, 12.

ERRATA.

Proceedings.

Page 10. Lines 27 and 40. *For* "Gardiner" *read* "Gardner."

Transactions.

Page 152. Lines 24 and 29. *For* "Dowson" *read* "Dawson."

Abstracts.

Page 19. No. 28. *For* "J. S. Ferguson" *read* "J. B. Ferguson."

Page 57. No. 99. *For* "**Textile**" *read* "**Tensile.**"

Page 207. No. 276. Throughout *for* "Palan" *read* "Palau."

D

BINDING LIST AUG 1 1946

TP
845
S73
v. 3

Society of Glass Technology,
Sheffield, Eng.
Journal

~~Physical &~~
~~Applied Sci.~~
~~Serials~~

Engineering

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE